



Research Article

Unlocking the Purgative, Antioxidant and Carbohydrate Enzyme Activating Powers of *Borassus aethiopum* Hypocotyl Ethanol Extract in Experimental Models

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ABSTRACT

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Constipation which occurs due to build-up of ROS and inhibition of carbohydrate (CHO) hydrolyzing enzyme(s) is treated with *Borassus aethiopum* by locals with no report to substantiate or refute the purported activity. This study therefore seeks to assess the purgative, antioxidant and CHO enzyme hydrolyzing property of *Borassus aethiopum* hypocotyl ethanol extract (BAHEE) in lomotil-induced constipated rats. Thirty Wistar rats of both sexes (158.25 ± 1.35 g) were assigned into 6 groups, A-F (n=5). Group A (control) received 1 ml of saline. Constipation was induced in groups B-F by oral administration of Lomotil (3 mg/kg body weight (BW) in saline for 48 h) and treated respectively with saline, senokot (reference drug [RD] at 50 mg/kg BW), 100, 200 and 400 mg/kg BW of BAHEE for seven days using oral gavage. Lomotil-induced constipation significantly ($p < 0.05$) decreased feed and water intake, faecal quality, body mass and gastrointestinal transit ratio. Lomotil also elevated serum level of malondialdehyde (MDA) and inhibited activities of α -amylase and α -glucosidase. Administration of BAHEE attenuated the constipative alterations, with the 400 mg/kg BW showing the best effect when compared with the RD. Also, the BAHEE substantively ($p < 0.05$) lowered the level of MDA and raised those of reduced glutathione (GSH) as well as activities of catalase (CAT), superoxide dismutase (SOD), glutathione peroxidase (GPx), α -amylase and α -glucosidase. *Borassus aethiopum* hypocotyl which could have acted in the treatment of constipation via enhancement of gastrointestinal motility and colonic peristalsis also showed antioxidant and carbohydrate enzyme activating property.

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INTRODUCTION

The inhibition of key regulatory enzymes (alpha amylase and alpha glucosidase) of carbohydrate catabolism is fundamental to the onset of

constipation. The enzyme inhibition, which occur along the carbohydrate digestive pathway, prevents the breakdown of complex carbohydrates into simple sugars, leading to

undigested carbohydrates reaching the large intestine, which can be fermented by bacteria, causing gas, bloating, abdominal discomfort, and potentially constipation by altering gut transit time and colonic mass (Derosa and Maffioli, 2012; Tessema *et al.*, 2020). Oxidative stress also contributes to the development of constipation (Hu *et al.*, 2024). The constipation-mediated by oxidative stress occur by damaging intestinal nerve cells (enteric neurons), disrupting the balance of gut bacteria (intestinal flora), and interfering with gut barrier function, which impairs intestinal motility and stool evacuation. This widespread cellular damage, caused by an excess of reactive oxygen species (ROS), leads to inflammation, reduced nerve function, and an imbalanced microbiome, all of which hinder the normal movement of waste through the colon. Oxidative/nitrosative stress, a pervasive condition of increased amounts of reactive and nitrogen species, is responsible for a variety of degenerative processes in some human diseases among which is constipation (Cao *et al.*, 2025).

Oxidative stress mediated constipation accounts for increased cellular development of malondialdehyde (MDA) in the gastrointestinal tract mucosa indicating an increase in lipid peroxidation (Maranon *et al.*, 2023). Enzymatic antioxidants including superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPx) play vital role in prevention of oxidative damage by reactive oxygen species that cause constipation (Forman and Zhang, 2021). Constipation is therefore defined as infrequent or difficult evacuation of faeces leading to water absorption, hardening of stool in colon and excessive straining (Soudy *et al.*, 2016). Also, the accumulation of starch due to inhibition of key regulatory enzyme like salivary α -amylase and α -glucosidase along the pathway involving the hydrolysis of starch to glucose can cause the development of constipation (Kim *et al.*, 2021).

Laxatives used for treatment of constipation presents discomfort and issues to user. However, medicinal plants used by locally have better effect with *Borassus aethiopum* as one choice plant.

Borassus aethiopum Mart. (family: *Arecaceae*), a plant species of *Borassus* palm, is mostly

known as African fan palm, *Muruchi* (Hausa, Northern Western Nigeria), *odo* (Igala, North Central, Nigeria) and *oku* (Tiv, North Central, Nigeria) (Jatau, 2008). A typical form of *B. aethiopum* is a solitary palm of 25m in height and 1m in width towards the bottom. It is widely cultivated in Nigeria, predominantly in Kaduna State and part of Nasarawa, Kano, Benue, Borno, Adamawa, Kebbi and Niger States, among others, where its hypocotyl is used as major food source, providing edible fruits and also a number of pharmacological uses (Sarkodie *et al.*, 2015). The rich phytochemical constituents of *Borassus aethiopum* hypocotyl can work singly or in combination to account for the pharmacological activities of the plant (Peprah *et al.*, 2018).

Documented properties of *B. aethiopum* hypocotyl include antioxidative and free radical-scavenging property (Amoateng *et al.*, 2010), androgenic (Adams *et al.*, 2025), physicochemical (Koffi *et al.*, 2010), antiplasmodial (Ali *et al.*, 2010), phytochemical (Gruca *et al.*, 2015), antimicrobial (Peprah *et al.*, 2018) and antidiabetic (Adams and Eze, 2022). Despite these studies, there is no report in the literature to substantiate or refute the purported use of the plant extract by locals as a laxative, creating a research gap that needs to be addressed. Therefore, this study seeks to assess the purgative, antioxidant and carbohydrate enzyme hydrolyzing property of *Borassus aethiopum* hypocotyl ethanol extract (BAHEE) in lomotil-induced constipated rats.

MATERIALS AND METHODS

Research Ethics consideration

Ethical clearance with reference number: (UAECAU/2024/022) was obtained from the ethical committee of the University of Abuja Ethics Committee on Animal Use following the stipulated procedures.

Chemicals and reagents

Lomotil was obtained from Pharmaffiliates, Haryana, India while Senokot was procured from Afrik Pharmaceuticals, Awo-Omamma, Nigeria. All other consumables, which are of diagnostic quality, are products of Afrab-Chem Ltd, Isolo Industrial Estate, Lagos and packaged using relevant sterile glassware and refined water. These materials were thereafter stored in clean reagent bottles until they are being used.

Plant collection and identification

Fresh *Borassus aethiopum* hypocotyl were collected from Jere, along Kaduna Road, Kagarko Local Government Area in Southern Kaduna State, Nigeria. It was identified and authenticated by Mr. Lateef A. Akeem of the Herbarium and Ethnobotany Unit, Medicinal Plant Research and Traditional Medicine (MPR&TM) Department, National Institute for Pharmaceutical Research and Development (NIPRD), Idu, F.C.T-Abuja, Nigeria where a Voucher Sample Identifier (NIPRD/H/7257) was assigned at the botanical garden for future use.

Experimental models

Albino rats of Wistar strain (135.63 ± 4.34 g) was obtained from the Animal Housing Unit of University of Abuja Veterinary Hospital. The animals which were kept in metallic compartment positioned in adequately ventilated cage (Heat: 28–31°C; Light: 12 hours; Humidity: 50–55%) were allowed to feed on rat pellet (Chidex Feeds, a product of Chidex Poultry Farm, Jikwoyi, Abuja, Nigeria) and clean water.

Assay kits, chemicals and medications

The assay kit for serum MDA were brands of Randox Laboratories Ltd., Co-Antrim, London.

Preparation of *Borassus aethiopum* hypocotyl ethanol extract

Fresh hypocotyl of *Borassus aethiopum* were air-dried under room condition till a constant weight was obtained. The dried samples were pulverized with an electric blender (Jiangmen Homemaster Electric Motors and Appliances Manufacturing Company Limited, Guangdong, China). A known weight of about 250 g of the powdered sample was extracted in 4L of ethanol (1:4) for a two-day period at room temperature. Filtration of the extract was done with a Whatman Number 1 porous paper with the corresponding mixture evaporated in a steam Lab bath (Model: KL-9325S, Mobile BSL Laboratories, 4 Sunshine Blvd, Ormond Beach, FL32174, USA) where it was exposed to dryness yielding 12.35 gram of bluish-green residue (ethanol extract). The extract was thereafter mixed with a little quantity of water to generate the needed dose levels (100, 200 and 400 mg/kg body weight [BW]) used in this study. The 100 and 200 mg/kg BW of the extract

correspond respectively, to a table spoon and a handful of the plant powder estimated to be consumed by an adult of 70 kg as a treatment for constipation. The 400 mg/kg BW of the extract which is quadruple-fold of the least dose was used to account for cases of ‘abuse’ by the users. The portions of powdered plant samples used locally were used to conduct a preliminary study to ascertain the dose selection used in this study.

Phytochemical screening of *Borassus aethiopum* hypocotyl ethanol extract

The procedure earlier described by Trease and Evans (1983) was followed for the screening of phytochemicals available in BAHEE.

Animal grouping and extract administration

Thirty Wistar rats were arranged in six groups (n = 5), and treated for seven days, as outlined below:

Group 1: Healthy rats + Saline

Group 2: Constipated rats + Distilled Water

Group 3: Constipated rats + Senokot (50 mg/kg BW)

Group 4: Constipated rats + 100 mg/kg BW of BAHEE

Group 5: Constipated rats + 200 mg/kg BW of BAHEE

Group 6: Constipated rats + 400 mg/kg BW of BAHEE

Procedure for determination of related constipation biomarkers

The procedure earlier described used by Kwon *et al* (2008), Elya *et al* (2012), Tsikas (2017), Camera *et al* (2001), Hamza and Hadwan (2020), Kanioura *et al* (2024), Reddy *et al* (1995) was adopted in this study for the determination of the level/activity of α -amylase, α -glucosidase, MDA, GSH, CAT, SOD, GP_x respectively.

Measurement of body weight, feed and water intake of animals

The procedure of Adams *et al* (2023) was adopted for this assessment. In brief, the weight of the feed and quantity of water were estimated every hour they were to be administered to the rats. About 50 minutes after, the remaining food was measured and the quantity of water measured. The difference between the first and last weight of the food and quantity of water, calculated for per day were taken as the day's dietary intake and water intake respectively. Furthermore, the weight of the rats was taken

separately prior to the start of the experiment for a 7-day experimental period to get the difference in body weight of the animals.

Total number, dry weight and water content of fecal pellets

The method described by Yakubu et al (2011) was adopted here. Briefly, the fecal pellets of individual rats were collected daily at 09:00 hour throughout the duration of the experiment. Total number, weight and water content of the pellets were computed as the difference between the weights of the wet and dry pellets.

Gastrointestinal transit (GIT) ratio

GIT ratio was determined according to the procedure described by Nagakura et al (1996) with little modification. Briefly, on the 8th day, 1 ml of orcein (3 g suspended in 50 ml of 0.5% carboxymethylcellulose) instead of carmine used by Nagakura et al (1996) was orally administered to the rats. One hour after administering the marker (orcein), the animals were sacrificed and the small intestines removed. The distance over which the orcein had travelled and the total length of the small intestine were measured. The GIT ratio was expressed as the percentage of the distance travelled by the orcein relative to the total length of the small intestine.

Collection of blood and preparation of serum

Collection blood and preparation of serum were done by adopting previously outlined procedures by Yakubu and Adams (2025). Briefly, the animals were made unconscious in a glass jar that contains cotton wool saturated in ethyl acetate. Blood (4 mls) was collected into plain sample bottles. The whole blood was separated using a Centrifuge (Farfly Energy Technology Co., Ltd, Model: ZJY-3, ShangHai, China) at 2000g for 10 minutes after which serum was obtained and refrigerated for 12 hours until it was used for assessment of purgative and antioxidant activity as well as estimation CHO hydrolyzing enzyme activity.

Statistical analysis of data obtained

Statistical tools including one-way analyses of variance (ANOVA), and the Duncan multiple range test (DMRT) were adopted to analyze statistical data from the experiments (n=5). SPSS Version 29 (International Business Machines [IBM] Company; Year of Release: 2022) was used to determine substantive differences at $p < 0.05$.

RESULTS

The phytochemical screening of BAHEE identified the presence of phytochemicals like phenolics, anthraquinone, tannins, steroids, flavonoids, phlobatannins, saponins and alkaloids while cardenolides and terpenoids were absent (Table 1).

Table 1: Phytochemical analysis of *Borassus aethiopum* hypocotyl ethanol extract

Phytochemical	Observation
Alkaloids	+
Saponins	+
Cardenolides	-
Phlobatannins	+
Flavonoids	+
Steroids	+
Tannins	+
Anthraquinone	+
Terpenoids	-
Phenolics	+

Key: (+) = Present; (-) = Absent

The induction of constipation with lomotil which significantly ($p < 0.05$) lowered water intake in the animals, did not significantly ($p > 0.05$) alter the feed intake (Table 2). The

administration of lomotil substantively ($p < 0.05$) lowered the number of fecal pellets, water content of fecal pellet and the weight of fecal

pellets when liken with the non-constipated (healthy) animals (Table 2).

Table 2: Fecal properties, feed and water intake of rat induced into constipation with lomotil

Parameters	Healthy rats	Constipated rats
Feed intake (g)	70.55±2.35 ^a	71.35±2.23 ^a
Water intake (ml)	145.28±3.42 ^a	139.62±3.54 ^b
Number of fecal pellets	245.75±5.15 ^a	198.75±4.25 ^b
Water content of fecal pellet (ml)	7.19±0.87 ^a	3.46±0.67 ^b
Weight of fecal pellets (g)	49.38±1.16 ^a	36.85±1.72 ^b

Outcomes are mean ± SEM of five rats.

Superscripted results (for constipated rats) that differ from those of their control (healthy rats), across the row, are substantively dissimilar ($p < 0.05$).

The administration of lomotil significantly ($p < 0.05$) reduced the feed and water intake when matched with the healthy/non-constipated animals. However, oral gavage of BAHEE at all doses (100, 200 and 400 mg/kg BW) sufficiently ($p < 0.05$) heightened the feed and water intake in a pattern comparable with that of the animals treated with the standard medication (senokot) and the non-constipated animals (Table 3). Administration of lomotil notably ($p < 0.05$) lowered the number of fecal pellets when matched-up with the healthy animals while all the administered doses of BAHEE elevated it when liken with the lomotil treated animals. The 100 mg/kg BW of BAHEE showed values for the number of fecal pellets that compared ($p > 0.05$) well with that of the 200 mg/kg BW dose of the extract (Table 3). Induction of constipation with lomotil substantively ($p < 0.05$) lowered the water content of fecal pellet while supplementation with all doses of BAHEE lowered it in a manner comparable ($p > 0.05$)

with that of the senokot-treated animals as well as the non-constipated animals. The administration of lomotil glaringly ($p < 0.05$) reduced the weight of fecal pellet when matched with the healthy animals however, oral gavage of all doses of BAHEE significantly ($p < 0.05$) heightened it. The 200 mg/kg BW of BAHEE showed values of the weight of fecal pellet that compared ($p > 0.05$) well with that of the 400 mg/kg BW of the extract (Table 3). Administration of lomotil sufficiently ($p < 0.05$) elevated the body weight of the animals when liken with that of the non-constipated animals. However, supplementation with all doses of BAHEE glaringly ($p < 0.05$) lowered the body weight gain. It is worthy of note that this observed reduction in the body weight gain by the extract at 200 and 400 mg/kg BW compared ($p > 0.05$) well with those of the senokot-treated animals and the non-constipated animals (Table 3).

Table 3: Effect of *Borassus aethiopum* hypocotyl ethanol extract on feed and water intake, body weight gain and fecal parameters of rats

Parameters	HR	CR	Senokot	Constipated Rats + <i>B. aethiopum</i> (mg/kg BW)		
				100	200	400
Feed intake (g)	95.24±2.42 ^a	82.21±3.62 ^b	94.02±2.24 ^a	95.24±3.45 ^a	94.49.61±2.53 ^a	95.12±2.72 ^a
Water intake (ml)	136.25±3.14 ^a	124.72±3.16 ^b	136.31±3.74 ^a	135.16±3.82 ^c	134.92±3.15 ^c	136.41±3.65 ^c
Number of fecal pellet	294.74±4.38 ^a	225.46±3.76 ^b	281.11±2.47 ^c	235.24±2.16 ^d	236.25±2.39 ^d	273.25±2.42 ^e
Water content of fecal pellets (ml)	8.21±1.24 ^a	5.12±1.38 ^b	9.34±1.28 ^a	10.14±1.83 ^a	8.65±1.48 ^a	9.33±1.34 ^a
Weight of fecal pellets (g)	58.14±2.13 ^a	22.31±2.75 ^b	50.16±2.36 ^c	46.24±2.78 ^d	49.39±2.86 ^c	51.24±2.21 ^c
Body weight gain (g)	17.25±1.26 ^a	29.39±2.26 ^b	18.45±1.82 ^a	14.24±1.56 ^c	17.69±1.55 ^a	16.38±1.35 ^a

Result presentations are mean ± SEM of five estimations. Superscripted results contrasting with the reference value for each parameter across the row are statistically dissimilar ($p < 0.05$).

HR = Healthy rats; **CR** = Constipated rats; **BW** = Body weight

Administration of lomotil substantially ($p < 0.05$) lowered the gastrointestinal transit ratio when matched-up with the non-constipated/healthy

animals. On the contrary, treatment of the constipated animals with all doses of BAHEE appreciably ($p < 0.05$) heightened it (Table 4).

Table 4: Effect of *Borassus aethiopum* hypocotyl ethanol extract on gastrointestinal transit ratio in rats with lomotil-induced constipation animals

Grouping	Gastrointestinal transit ratio
Healthy rats + Saline	42.25±3.38 ^a
Constipated rats + DW	27.44±1.21 ^b
Constipated rats + Senokot	36.29±1.54 ^c
Constipated rats + 100 mg/kg BW	48.83±1.37 ^d
Constipated rats + 200 mg/kg BW	39.25±2.27 ^e
Constipated rats + 400 mg/kg BW	57.14±3.16 ^f

n = 3 ± SEM

Values carrying superscript varying from with the reference value for each parameter down the group are significantly different ($p < 0.05$)

DW = Distilled water; **BW** = Body weight

Administration of lomotil substantially ($p < 0.05$) lowered the activities of serum alpha amylase and alpha glucosidase when liken with the healthy/non-constipated animals. On the contrary, treatment of the constipated animals

with all graded dose of BAHEE appreciably ($p < 0.05$) increased serum alpha amylase and alpha glucosidase activities in a manner not comparable with the senokot-treated animals (Table 5).

Table 5: Serum carbohydrate hydrolyzing enzyme activity of lomotil-induced constipated rats after exposure to *Borassus aethiopum* hypocotyl ethanol extract

Treatment Group	α -amylase (U/L)	α -glucosidase (U/L)
HR + Saline	3.38 $\pm$ 1.24 ^a	2.88 $\pm$ 1.7
CR + DW	0.85 $\pm$ 0.05 ^b	0.68 $\pm$ 0.0
CR + Senokot	5.32 $\pm$ 1.35 ^c	4.85 $\pm$ 1.76 ^c
CR + 100 mg/kg BW of BAHEE	8.52 $\pm$ 2.87 ^d	7.93 $\pm$ 2.37 ^d
CR + 200 mg/kg BW of BAHEE	15.67 $\pm$ 3.08 ^e	10.75 $\pm$ 3.15 ^e
CR + 400 mg/kg BW of BAHEE	12.34 $\pm$ 3.45 ^f	13.28 $\pm$ 3.62 ^f

Presented data are mean $\pm$ SEM of five collections. Superscripted values differing from their respective control values, down the column, are substantially different ($p < 0.05$).

HR = Healthy rats; **CR** = Constipated rats; **DW** = Distilled water; **α** = alpha; **BW** = Body weight

Administration of lomotil substantially ($p < 0.05$) raised the concentration of serum MDA when compared with the healthy/non-constipated animals. However, treatment of the constipated animals with all doses of BAHEE sufficiently lowered the level of serum MDA. The reduction in serum MDA was in a manner not comparable with those of the senokot-treated animals (Table 6). The administration of lomotil statistically

($p < 0.05$) lowered serum GSH concentration when matched with the healthy/non-constipated animals. In contrast, the oral gavage of all doses of BAHEE glaringly ($p < 0.05$) heightened the concentration of serum GSH when liken with the constipated animals treated with DW (Table 6).

Table 6: Serum antioxidant status of lomotil-induced constipated rats after exposure to *Borassus aethiopum* hypocotyl ethanol extract

Treatment Group	Malondialdehyde (MDA) (nmol/mg protein)	Reduced Glutathione (GSH) (nmol/mg protein)
HR + Saline	2.59 $\pm$ 0.08 ^a	6.02 $\pm$ 1.36 ^a
CR + DW	25.34 $\pm$ 1.25 ^b	2.35 $\pm$ 0.08 ^b
CR + Senokot	5.52 $\pm$ 1.38 ^c	9.55 $\pm$ 2.67 ^c
CR + 100 mg/kg BW of BAHEE	13.75 $\pm$ 3.65 ^d	15.85 $\pm$ 3.56 ^d
CR + 200 mg/kg BW of BAHEE	9.78 $\pm$ 2.84 ^e	37.28 $\pm$ 5.94 ^e
CR + 400 mg/kg BW of BAHEE	16.04 $\pm$ 4.72 ^f	23.16 $\pm$ 3.82 ^f

The presented results are mean $\pm$ SEM of five estimations. Superscripted results that differ from their respective control results down the column are substantively different ($p < 0.05$).

HR = Healthy rats; **CR** = Constipated rats; **DW** = Distilled water; **BW** = Body weight

The administration of lomotil appreciably ($p < 0.05$) reduced serum activities of CAT, SOD and GP_x when matched with the healthy/non-constipated animals. However, supplementation with all examined doses of BAHEE glaringly

($p < 0.05$) heightened the serum activities of the enzymes. The increase in serum SOD activity by BAHEE was in a dose-dependent manner. It is important to note that, while the 200 dose of BAHEE gave a better serum CAT activity than

the 400 dose, the 100 dose of BAHEE showed a better serum GP_x activity than the 200 dose (Table 7).

Table 7: Serum antioxidant enzyme activity of lomotil-induced constipated rats after exposure to *Borassus aethiopum* hypocotyl ethanol extract

Treatment Group	CAT (nmol/min/mg protein)	SOD (nmol/min/mg protein)	GP _x (nmol/min/mg protein)
HR + Saline	9.55±2.38 ^a	26.78±1.95 ^a	52.15±2.78 ^a
CR + DW	5.26±1.45 ^b	15.25±1.72 ^b	10.39±1.83 ^b
CR + Senokot	12.35±2.92 ^c	42.33±2.18 ^c	65.79±2.84 ^c
CR + 100 mg/kg BW of BAHEE	18.19±3.71 ^d	99.78±4.35 ^d	122.63±4.92 ^d
CR + 200 mg/kg BW of BAHEE	34.12±4.27 ^e	141.54±4.87 ^e	88.29±3.44 ^e
CR + 400 mg/kg BW of BAHEE	25.72±3.08 ^f	178.65±5.37 ^f	151.19±5.27 ^f

Data are mean ± SEM of five rats. Superscript figures that are different from their respective control figures, down the column, are significantly different ($p < 0.05$)

HR = Healthy rats; **CR** = Constipated rats; **DW** = Distilled water; **BW** = Body weight; **CAT** = Catalase; **SOD** = Superoxide dismutase; **GP_x** = Glutathione peroxidase

DISCUSSION

The evaluation of medicinal plants with purgative property can provide a paradigm shift from the use of conventional medications, which often present with side effects, to alternative and complementary ones with better mode of therapeutic action (via stimulation of antioxidative and carbohydrate hydrolyzing enzyme activity) and reduced toxicity (Adams *et al.*, 2023).

Feed and water intake gives an insight into food/fluid consumption, type/pattern of dietary fibre ingested, food/liquid interaction as well as stool softening rate in a constipation state. Fecal properties help in the measurement of constipation state, assessment of stool characteristic features and indication of gastrointestinal transit (Wang *et al.*, 2025). Therefore, the increase in the number of fecal pellets, water content of pellets and weight of fecal pellets by BAHEE may stimulate gastrointestinal (GI) motility. The increase in feed and water intake by BAHEE indicates improved overall fluid intake, which contributes to softer stools and easier passage as well as overall normalization of fecal parameters and enhanced motility indicating a positive effect on the digestive process. Other possible mechanisms of

action by BAHEE could be via increase in water content of fecal pellets which is a key factor in relieving constipation, increased gastrointestinal (GI) motility, which is the movement of food and waste through the digestive tract, thus enabling fast transit to move stool through the intestines more efficiently as well as normalization of the frequency and consistency of bowel movements (Nakajima *et al.*, 2023). This increase in feed and water intake is in agreement with those of Yakubu *et al.* (2011) who observed similar findings.

The increase in number, water content and weight of fecal pellet by BAHEE could indicate reduction in constipation by softening of stool and increasing bowel movement. This may also be due to the ability of BAHEE to increase intestinal fluid accumulation and promote gastrointestinal (GI) motility thus helping to easily move stool through the digestive tract. This increased number of fecal pellets could have occurred via enhanced laxative effects by BAHEE leading to greater frequency of defecation, resulting in a higher number of fecal pellets over a given period. The increased fecal water content could have occurred via increase in percentage of water in the feces by BAHEE, which softens the stool, making it easier to pass (Ayele

and Kawet, 2024). The increase fecal weight could have occurred by addition of water content naturally which increases the overall weight of the fecal matter. The overall effect of BAHEE promoted fast movement of the digestive tract (GI motility) and trigger of more fluid to accumulate in the intestines, both contributing to the laxative effect of the plant extract (Ma *et al.*, 2025).

The decrease in body weight gain by BAHEE could occur via stimulation of bowel movements leading to increased frequency and volume of fecal output thus reducing the total amount of retained matter and potentially lower body weight gain (Hong *et al.*, 2024), influence on the gut microbiota leading to increased short-chain fatty acid (SCFA) production and a healthier gut environment which may contribute to weight management by influencing metabolism and fat storage, effect on lipid metabolism and overall energy expenditure which could contribute to reduced body weight gain even in a calorie deficit state, improvement in overall physiological state of the animal, which can, in turn, affect body weight gain over prolonged period (Shen *et al.*, 2024).

The gastrointestinal transit ratio is a measurement that indicates the rate at which a substance travels through the digestive tract, and is derived by dividing the distance the substance has traveled by the total length of the intestine. To measure it, a substance (like a charcoal meal, stable isotopes, or paracetamol) is ingested, and at specific time points, the substance's location is determined, often after the animal is euthanized or through non-invasive imaging for humans. The results help localize and diagnose transit abnormalities, guiding therapeutic decisions (Guarize *et al.*, 2012). Therefore, the increased gastrointestinal transit ratio in this study by BAHEE may indicate an acceleration of food moving through the digestive tract, which promotes the enhancement of intestinal motility, increasing fecal water content, stimulating the secretion of intestinal fluids, and influencing the smooth muscles of the gut. These observed effects, in the present study, may be adduced to the presence of secondary metabolites inherent in BAHEE, such as flavonoids and saponins, which may facilitate gastrointestinal transit and bowel movement (Khakisahneh *et al.*, 2025). The possible mode of action for increased gastrointestinal transit ratio by BAHEE could be via propulsion of intestinal contents, secretion of fluids and electrolytes into the intestinal lumen, which can enhance transit,

stimulation of smooth muscle contractions in the gut which is essential for peristalsis, activation of muscarinic acetylcholine receptors (mAChRs) which play a role in regulating intestinal motility and stool excretion as well as increase in the amount of water in the feces which helps to soften stools and facilitate their passage (Ayari *et al.*, 2025). The enhanced gastrointestinal transit ratio observed in this study was in agreement with that of Meite *et al.* (2010).

Alpha (α)-amylase is an enzyme that catabolizes carbohydrates (polysaccharides) like starch into smaller sugars, mainly dextrin. It is found as salivary and pancreatic alpha amylase in human, plants, and microorganisms where they play vital role in carbohydrate digestion (Shalini *et al.*, 2025). The decrease in serum α -amylase activity after induction of lomolil indicates the role of lomolil to predispose to constipation as they act as α -amylase inhibitors by blocking/inhibiting the activity of the enzyme from breaking down starch to dextrin, causing constipation. This inhibition could delay the action of α -amylase enzymes to digest carbohydrate and prolong the overall carbohydrate digestion time thereby lowering the absorption of glucose and consequently reducing the postprandial plasma glucose. These inhibitors could be employed as an oral antihyperglycemic medication especially in persons with hyperglycaemia/diabetes mellitus (Oladiipo *et al.*, 2024). However, the increase in α -amylase activity by BAHEE at all doses may suggest activation of the catalytic activity of the enzyme which facilitates carbohydrate digestion (starch to dextrin and to glucose), thus reducing starch accumulation and preventing the onset of constipation (Loukili *et al.*, 2025). Alpha (α)-glucosidase are enzymes involved in the break down of dietary dextrin to maltose (Wei *et al.*, 2023). The increase in α -glucosidase activity in this study by BAHEE at all doses indicates the ability of the extract to facilitate the conversion of oligosaccharide to disaccharide, thus enhancing carbohydrate (oligosaccharide) digestion and prevention of the onset of constipation (Saliu *et al.*, 2025). These activations on α -amylase and α -glucosidase activity by BAHEE underscores the capacity of the extract to act as a carbohydrate enzyme activating (laxative) agent, thus preventing eventual development of constipation.

Malondialdehyde (MDA) is a reactive aldehyde and a principal product of lipid peroxidation, a process in which polyunsaturated fatty acids are

catabolized by free radicals. MDA is a biomarker for oxidative stress (lipid peroxidation) in biological samples and is associated with cellular damage, inflammation, and various pathological conditions among which is constipation. Due to its toxic and mutagenic properties, its presence indicates increased reactive oxygen species (ROS) and damage to lipids, proteins, and DNA within the biological system (Eze *et al.*, 2018). The increased in MDA concentration by lomotil it contributes to it by causing/inducing oxidative stress and inflammation in the intestines, which can lead to reduced intestinal peristalsis, impaired digestive enzyme activity, and damage to the intestinal mucosa, and impaired intestinal immunity, all factors that hinder normal bowel function and contribute to constipation (Zhou *et al.*, 2025). The reduction in serum MDA level by BAHEE may imply the ability of the extract to reduce oxidative stress and improve intestinal health (Chen *et al.*, 2024).

Reduced Glutathione (GSH) is an important non-enzymic antioxidant in biological cells, against ROS and free radicals that contributes to the onset of constipation. GSH exists as the active and reduced form of glutathione that neutralizes free radicals. Meanwhile, the oxidized form of glutathione (GSSG) is recycled back into the reduced form by the biological system to maintain a balance and body homeostasis (Averill-Bates, 2023). The increase in serum GSH level by all doses of BAHEE may be adduced to its ability to improve constipation by boosting reduced glutathione levels and improving antioxidant defense mechanisms, which counteracts oxidative stress often associated with constipation. The increase in serum GSH concentration by BAHEE could have acted by increasing fecal water content, accelerating intestinal transit and alleviating symptoms of constipation without causing diarrhea (Song *et al.*, 2025). This demonstrated the antioxidant potential of BAHEE in the constipated animals.

Catalase (CAT) is a ubiquitous enzyme found in almost all living organisms that protects cells from oxidative damage by catalyzing the decomposition of hydrogen peroxide into water and oxygen. It is a key component of antioxidant systems that neutralizes ROS to prevent cellular damage. CAT possess enzymic antioxidant property in reducing inflammation associated with intestinal conditions that occur during constipation (Rasheed, 2024). The increase in serum CAT concentration by all

doses of BAHEE, in this study, could signify its ability to break down hydrogen peroxide, a reactive oxygen species (ROS), which might have otherwise damaged the intestinal lining and contributed to inflammation in conditions like inflammatory bowel disease (IBD) in the animals (Ayari *et al.*, 2024). This action indicates that BAHEE exhibits antioxidant activity against ROS and oxidative stress caused by induction of constipation via induction of lomotil.

Superoxide dismutase (SOD) is a crucial antioxidant enzyme that protects cells from damage by converting harmful superoxide radicals (O_2^-) into hydrogen peroxide (H_2O_2) and molecular oxygen (O_2). By preventing the accumulation of ROS, SOD maintains cellular redox balance, protects DNA and other macromolecules from oxidative damage, and plays a role in various physiological processes. The intestine, colon and the entire GIT are among the cellular structures that benefit from the function (Anwar *et al.*, 2025). Therefore, the increase in serum SOD concentration by all doses of BAHEE may be attributed to the ability of the extract to modulate SOD via enhancement of gut motility as well as mitigation/reduction of lipid peroxidation, oxidative damage/stress within the colon, thus promoting gut health and restoring intestinal balance (Lee *et al.*, 2024). This role confers antioxidant property on BAHEE against lomotil-induced constipation in animals.

Glutathione peroxidase (GP_x) is an enzymic antioxidant that offers protection against lipid peroxidation by catalytically reducing harmful lipid hydroperoxides (LOOH) to less reactive lipid alcohols, using the tripeptide glutathione (GSH) as an electron donor. This enzymatic activity is vital for maintaining the integrity of cell membranes and preventing oxidative damage caused by free radicals in the gastrointestinal tract (Pei *et al.*, 2023). The increased serum GP_x level by BAHEE in this study could reduce the harmful ROS and lipid peroxides, which might damage intestinal cells and impair mucosal barrier function. By maintaining redox homeostasis. Also, the extract might help preserve the integrity of the intestinal lining and support normal peristalsis, thereby potentially alleviating constipation, thus conferring antioxidant ability on the plant extract.

Medicinal plants possess vital phytoconstituents that function as laxatives against constipation in man and experimental models via several modes of action. Anthraquinones are naturally occurring

stimulant laxatives which facilitates the stimulation of intestinal muscle contractions (motility) and promotion of the easy movement of stool through the colon. Saponins are involved in relieving with constipation via activation of intestinal muscle contractions and increase in secretion of chloride ions in the colon, which helps in softening of stools (Azlan *et al.*, 2025). Tannins are responsible for relieving constipation via improvement in intestinal motility and normalization of stool properties (Ma *et al.*, 2022). Flavonoids play a major role in increasing secretion of chloride in the colon, which softens stool and helps in the treatment of constipation. Alkaloids contributed to the laxative effect of BAHEE by increasing fecal water content, accelerating gastrointestinal transit, stimulating intestinal fluid secretion and stimulating the muscles of the digestive tract to easily excrete stools (Chiarioni *et al.*, 2023). This is akin to the study by Longanga-Otshudi *et al.* (2000) who identified similar phytoconstituents with purgative activity. Given the several functions performed by the phytoconstituents of the plant, the purgative activity of the BAHEE, in the present study, may be attributed to the phytochemicals inherent in the plant hypocotyl.

CONCLUSION

Findings from the study indicated that *Borassus aethiopum* hypocotyl demonstrated purgative property via enhancement of gastrointestinal motility and colonic peristalsis. The plant showed carbohydrate enzyme activating effect by enhancing the activity of inhibited carbohydrate hydrolyzing enzymes. The plant also exhibited antioxidative effect by lowering the elevated biomarkers of oxidative stress in rats. The plant extract may be explored for the treatment of constipation. The histological examination of the intestine to correlate the structural architecture with the functional activity as well as other mechanistic assays for further insight into the mode of action of the plant extract should be considered.

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REFERENCES

Adams, M.D. and Eze, E.D. (2022). *Borassus aethiopum* (Mart.) ethanol fruit extract reverses alloxan-treatment alterations in experimental animals.

Mediterranean Journal of Nutrition and Metabolism, 15 (2022), 429-445. DOI:10.3233/MNM-211589.

Adams, M.D., Muftaudeen, T.K. and Saliu, O.A. (2023). Polyphenol-rich extract of *Digitaria exilis* (Kippist) grain lowers gastrointestinal dysmotility and enhanced colonic peristalsis in rifaximin-induced constipated rats. *Nigerian Journal of Biochemistry and Molecular Biology*, 38(3), 131-138. <https://dx.doi.org/10.4314/njbmb.v38i3.4>.

Adams, M.D., Sharubutu, B.G. and Olaolu, T.D. (2025). Molecular docking, HPLC phytochemical profiling and androgenic property of ethylacetate fraction of *Borassus aethiopum* (Mart.) hypocotyl in pre-clinical models. *Journal of Ethnopharmacology*, 354(2026), 120494. <https://doi.org/10.1016/j.jep.2025.120494>.

Ali, A., Alhadji, D., Tchiegang, C. and Saidou, C. (2010). Physico-chemical properties of palmyra palm (*Borassus aethiopum* Mart.) fruits from Northern Cameroon. *African Journal of Food Science*, 4(3), 115-119.

Amoateng, P., Kumah, D.B. and Koffuor, G. (2010). Antioxidant and free radical scavenging properties of an aqueous ripe fruit extract of *Borassus aethiopum*. *West African Journal of Pharmacology*, 26(1):8-14. DOI:10.4314/wajpdr.v26i1.70055.

Averill-Bates, D.A. (2023). The antioxidant glutathione. *Vitamins and Hormones*, 121, 109-141. doi: 10.1016/bs.vh.2022.09.002.

Anwar, S., Sarwar, T., Khan, A.A. and Rahmani, A.H. (2025). Therapeutic Applications and Mechanisms of Superoxide Dismutase (SOD) in Different Pathogenesis. *Biomolecules*, 15(8), 1130. doi: 10.3390/biom15081130.

Ayari, A., Dakhli, N., Jedidi S, Sammari, H., Arrari, F. and Hichem Sebai, H. (2024). Laxative and purgative actions of phytoactive compounds from beetroot juice against loperamide- induced constipation, oxidative stress, and inflammation in rats. *Neurogastroenterology and Motility*, 7(1), e14935. <https://doi.org/10.1111/nmo.14935>.

- Ayari, A., Jedidi, S., Sammari, H., Dhawefi, N., Wahabi, S. and Sebai, H. (2025). Beetroot leaf extract enhances gut motility in a model of loperamide-induced constipation in male rats: A phytopharmacological study. *Physiological Reports*, 13(17), e70467. doi: 10.14814/phy2.70467.
- Ayele, A.G. and Kawet, J.S. (2024). Evaluations of the *in vivo* Laxative Effects of Aqueous Leaf and Stem Extracts of *Artemisia Abyssinica* in Mice. *Journal of Experimental Pharmacology*, 16, 135-142. doi: 10.2147/JEP.S456029.
- Azlan, N.A., Zaharudin, N.S., Suhaidah, M.J. and Yan, C.C. (2025). Medicinal plants used for the management of constipation: A systematic review. *Medicinal Plants - International Journal of Phytomedicines and Related Industries*, 17(2), 225-235. DOI: 10.5958/09756892.2025.00023.7.
- Camera, E., Rinaldi, M., Briganti, S., Picardo, M. and Fanali, S. (2001). Simultaneous determination of reduced and oxidized glutathione in peripheral blood mononuclear cells by liquid chromatography–electrospray mass spectrometry. *Journal of Chromatography B: Biomedical Sciences and Applications*, 757(1), 69–78. [https://doi.org/10.1016/S0378347\(01\)00081-0](https://doi.org/10.1016/S0378347(01)00081-0).
- Cao, Y., Yang, Z. and Tang, Q. (2025). The association between oxidative balance score with constipation and diarrhea in US adults: a cross-sectional analysis of NHANES 2007- 2010. *BMC Gastroenterology*, 25(1), 29. doi: 10.1186/s12876-025-03597-5.
- Chen, K.D., Wang, K.L., Chen, C., Zhu, Y.J., Tang, W.W., Wang, Y.J., Chen, Z.P., He, L.H., Chen, Y.G. and Zhang, W. (2024). Hydrogen-rich water alleviates constipation by attenuating oxidative stress through the sirtuin1/nuclear factor-erythroid-2-related factor 2/heme oxygenase-1 signaling pathway. *World Journal of Gastroenterology*, 30(20), 2709-2725. doi: 10.3748/wjg.v30.i20.2709.
- Chiarioni, G., Popa, S.L., Ismaiel, A., Pop, C., Dumitrascu, D.I., Brata, V.D., Duse, T.A., Incze, V. and Surdea-Blaga, T. (2023). Herbal Remedies for Constipation-Predominant Irritable Bowel Syndrome: A Systematic Review of Randomized Controlled Trials. *Nutrients*, 15(19), 4216. doi: 10.3390/nu15194216.
- Derosa, G. and Maffioli P. (2012). α -Glucosidase inhibitors and their use in clinical practice. *Archives of Medical Sciences*, 8(5), 899-906. DOI: 10.5114/aoms.2012.31621.
- Eze, E.D., Afodun, A.M., Sulaiman, S.O., Ponsiano, N., Iliya, E., Adams, M.D., Okpanachi, A.O. and Rabiou, K.M. (2018). Lycopene attenuates diabetes-induced oxidative stress in Wistar rats. *Journal of Diabetes and Endocrinology*, 9(2), 11-19. DOI: 10.5897/JDE2018.0118.
- Forman, H.J. and Zhang, H. (2021). Targeting oxidative stress in disease: Promise and limitations of antioxidant therapy. *Nature Reviews Drug Discovery*, 20, 689-709. doi: 10.1038/s41573-021-00233-1.
- Gruca, M., Yu, W., Amoateng, P., Nielsen, M.A., Poulsen, T.B. and Balslev, H. (2015). Ethnomedicinal survey and *in vitro* anti-plasmodial activity of the palm *Borassus aethiopum* Mart. *Journal of Ethnopharmacology*, 175, 356-69. doi: 10.1016/j.jep.2015.09.010.
- Hamza, T.A. and Hadwan, M.H. (2020). New spectrophotometric method for the assessment of catalase enzyme activity in biological tissues. *Current Analytical Chemistry*, 16(8), 1054–1062. DOI: 10.2174/1573411016666200116091238.
- Hong, Y., Chen, X. and Liu, J. (2024). Analysis of Factors Associated with Constipation in the Population with Obesity: Evidence from the National Health and Nutrition Examination Survey. *Obesity Facts*, 17(2), 169-182. doi: 10.1159/000536318.
- Hu, J., Zou, H., Qiao, X., Wang, Y., Ly, M., Zhang, K. and Wang, F. (2024). The relationship between oxidative balance scores and chronic diarrhea and constipation: a population-based study. *BMC Public Health*. 24, 1366. <https://doi.org/10.1186/s12889-024-18683-8>.
- Jatau, D. (2008). Assessment of *Borassus aethiopum* (Mart). Marketing in Adamawa

- State, Nigeria. *Journal of Agricultural and Social Sciences*, 4(4), 159-164.
- Kanioura, A., Geka, G., Kochylas, I., Likodimos, V., Gardelis, S., Dimitriou, A., Papanikolaou, N., Kakabakos, S. and Petrou, P. (2024). Superoxide Dismutase Detection on Silver \Nanostructured Substrates through Surface-Enhanced Spectroscopic Techniques. *Chemosensors*, 12(6), 89. <https://doi.org/10.3390/chemosensors12060089>.
- Khakisahneh, S., Wang, JH., Zhang, XY., Choi, Y., Yi-Han, S., Song, E., Nam Y. and Kim, H. (2025). Comparative evaluation of two herbal formulas for gastrointestinal function and gut microbiota modulation in rats with loperamide-induced dyspepsia. *Scientific Reports*, 15, 31186. <https://doi.org/10.1038/s41598-025-15574-9>.
- Kim, J.E., Choi, Y.J., Gong, J.E., Jin, Y.J., Park, S.H. and Hwang, D.Y. (2021). Laxative effect of phlorotannins derived from *Ecklonia cava* on loperamide-induced constipation in SD rats. *Molecules*, 26(23), 7209. doi: 10.3390/molecules26237209.
- Koffi, E.K., Ezoua, P., Sidibe, D. and Agbo, N.G. (2010). Sensory analysis of the fruit juice of palmyrah palm (*Borassus aethiopum*): a decision-making tool. *African Journal of Food Agriculture, Nutrition and Development*, 10(7), 2818-33. DOI:10.4314/ajfand.v10i7.59028.
- Lee, H., Hossain M.K., Kim S., Jeong P., Lee, G., Kim, D., Chung, M.J. and Chae, H. (2024). Improving intestinal health and mitigating Loperamide-Induced constipation through the modulation of Aquaporin-3 expression, reduction of oxidative stress, and suppression of inflammatory response by fermented rice extract. *Journal of Functional Foods*, 121, 106444. <https://doi.org/10.1016/j.jff.2024.106444>.
- Longanga-Otshudi, A., Vercruyse A. and Foriers, A. (2000). Contribution to the ethnobotanical, phytochemical and pharmacological studies of traditionally used medicinal plants in the treatment of dysentery and diarrhea in Lomela area, Democratic Republic of Congo (DRC) *Journal of Ethnopharmacology*, 71:411–423. doi: 10.1016/S0378-8741(00)00167-7.
- Loukili, E.H., Fadil, M., Elrherabi, A., Er-Rajy, M., Taibi, M., Azzaoui, K., Salghi, R., Sabbahi, R., Alanazi, M.M., Rhazi, L., Szechenyi, A., Siaj, M. and Hammouti, B. (2025). Inhibition of carbohydrate digestive enzymes by a complementary essential oil blend: *in silico* and mixture design approaches. *Frontiers in Pharmacology*, 16, 1522124. doi: 10.3389/fphar.
- Ma, Q., Wang, C., Richard, S.W., Bian, Z. and Yuan, C.S. (2022). Herbal Medicines for Constipation and Phytochemical Comparison of Active Components. *The American Journal of Chinese Medicine*, 50(3), 1-10. DOI:10.1142/S0192415X2250029X.
- Ma, T., Zhou, M., Zhang, X., Zhang, R., Wei, Y. and Liu, J. (2025). Mung Bean Starch-Derived Fermented Liquid Alleviates Constipation via 5-HT Modulation and Gut Microbiota Regulation: An *In Vivo* Study. *Foods*, 14(14), 2483. <https://doi.org/10.3390/foods14142483>.
- Maranon, J.A., Nanez-Valdivieso, J., Torrecillas-Mosquero, V. and Hernandez-Bueno, A. (2023). Benefits of Mallolax on the restoration of the antioxidant defenses in intestinal mucosal barrier depleted by constipation. *American Journal of Gastroenterology and. Hepatology*, 4(1), 1024.
- Meite, S., Bahi, C., Yeo, D., Datte, J.Y., Djaman, J.A. and N'guessan, D.J. (2010). Laxative activities of *Mareya micrantha* (Benth.) Müll. Arg. (*Euphorbiaceae*) leaf aqueous extract in rats. *BMC Complementary and Alternative Medicine*, 10(7), 1-6. doi: 10.1186/1472-6882-10-7.
- Nagakura, Y., Naitoh, Y., Kamato, T., Yamano, M. and Miyata, K. (1996). Compounds processing 5-HT₃ receptor antagonistic activity inhibit intestinal propulsion in mice. *European Journal of Pharmacology*, 311(1), 67-72. doi: 10.1016/0014-2999(96)00403-7.

- Nakajima, A, Takano, H, Kamada, Y, Sakai, S, Ichikawa, M. and Igarashi, A. (2023). High-fiber liquid diet for chronic constipation: An exploration from healthcare providers' survey results. *Clinical Nutrition Open Science*, 52, 34-48. <https://doi.org/10.1016/j.nutos.2023.09.002>.
- Oladipo, S.D., Luckay, R.C. and Olofinson, K.A. (2024). Evaluating the antidiabetes and antioxidant activities of halogenated Schiff bases derived from 4-(diethylamino)salicylaldehyde: *in vitro* antidiabetes, antioxidant and computational investigation. *Scientific Reports*, 14, 27073. <https://doi.org/10.1038/s41598-024-78460-w>.
- Pei, J., Pan, X., Wei, G. and Hua, Y. (2023). Research progress of glutathione peroxidase family (GPx) in redoxidation. *Frontiers in Pharmacology*, 14, 1147414. doi: 10.3389/fphar.2023.1147414.
- Peprah, M., Apprey, C., Larbie, C. and Asamoah-Boaky, O. (2018). Phytochemical constituents of flour and composite bread from African Palmyra (*Borassus aethiopum*) fruit from Ghana. *European Journal of Medicinal Plants*, 23(1), 1-7. DOI: 10.9734/EJMP/2018/40502.
- Rasheed, Z. (2024). Therapeutic potentials of catalase: Mechanisms, applications, and future perspectives. *International Journal of Health Sciences (Qassim)*, 18(2), 1-6.
- Saliu, O.A., Edogbo, B., Tijjani, H., Idowu, O.A., Adamu, S.U., Nasir, S., Sada, S.A., Adams, M.D. and Saliu, N.B. (2025). *In vitro* Antioxidant and Antihyperglycemia Properties of Verbenone Enhanced with Selected Solubilizing Compounds. *FULafia Journal of Science and Technology*, 9(2), 36-42. <https://doi.org/10.62050/fjst2025.v9n2.468>.
- Sarkodie, A.J., Squire, A.S., Kretchy, A.I., Bekoe, O.E., Domozero, Y.F.C., Ahiagbe, M.J.K., Adjei, E., Edoh, A.D., Amponsah, K.I., Sakyiama, M., Lamptey, K.V., Affedzi-Obresi, S., Duncan, L.J., Debrah, P., N'guessan, B.B. and Nyarko, K.A. (2015). *Borassus aethiopum*, A Potential Medicinal Source of Antioxidants, Anti-Inflammatory and Antimicrobial Agents. *Herbal Medicine*, 1, 1-3.
- Shen, X, Gong, L., Li, R., Huang N., Zhang, H., Chen S., Liu Y. and Sun, R. (2024). Treatment of constipation with Aloe and its compatibility prescriptions. *Chinese Herbal Medicines*, 16(4), 561-571. <https://doi.org/10.1016/j.chmed.2024.07.005>.
- Shalini, S., Rakshana, N. and Menaka R. (2025). Evaluation of Alpha-Amylase and Alpha-Glucosidase Activities of Brahmi Nei: An *In-Vitro* Study. *Journal of Advances in Medical and Pharmaceutical Sciences*, 27(3), 46-53. <https://doi.org/10.9734/jamps/2025/v27i3757>.
- Song, H.J., Seol, A., Park, J., Kim, J.-E., Kim, T.-R., Park, K.-H., Park, E.-S., Lim, S.-J., Wang, S.H., Sung, J.E., Choi, Y., Lee, H., & Hwang, D.Y. (2025). Antioxidant and Laxative Effects of Methanol Extracts of Green Pine Cones (*Pinus densiflora*) in Sprague-Dawley Rats with Loperamide-Induced Constipation. *Antioxidants*, 14(1), 37. <https://doi.org/10.3390/antiox14010037>.
- Soudy, I.D., Abdelaziz, A.I. Alhadi, D. and Hassane, H.M. (2016). Laxative Effect of Some Plants Extracts Used in Traditional Pharmacopoeia on the Intestine of Rabbit. *Food and Nutrition Sciences*, 07(12), 1182-1190. DOI: 10.4236/fns.2016.712110.
- Tessema, M.Y., Wubneh, Z.B. and Asrie, A.B. (2020). Laxative Activities of 80% Methanolic Extract of the Leaves of *Grewia ferruginea* Hochst Ex A Rich in Mice. *Journal of Evidence Based Integrative Medicine*, 25, 2515690X20926922. doi: 10.1177/2515690X20926922.
- Trease, G.E. and Evans, W.C. (1983). A Textbook of Pharmacognosy, Twelfth ed. Bailliere-Tindall Ltd., London, pp. 343-383.
- Tsikis, D. (2017). Assessment of Lipid Peroxidation by Measuring

- Malondialdehyde (MDA) and Relatives in Biological Samples: Analytical and Biological Challenges. *Analytical Biochemistry*, 524, 13-30. <https://doi.org/10.1016/j.ab.2016.10.02>
- Wang, D.C., Peng, X.F., Chen, W.X. and Yu, M. (2025). The Association of moisture intake and constipation among us adults: evidence from NHANES 2005–2010. *BMC Public Health*, 25, 399. <https://doi.org/10.1186/s12889-025-21346-x>.
- Wei, L., Ji, L., Miao Y., Han, X., Li, Y., Wang, Z., Fu J., Guo, L., Su, Y. and Zhang, Y. (2023). Constipation in DM are associated with both poor glycemic control and diabetic complications: Current status and future directions. *Biomedicine and Pharmacotherapy*, 165, 115202. <https://doi.org/10.1016/j.biopha.2023.115202>.
- Yakubu, M.T., Adams, M.D., Akanji, M.A. and Oladiji, A.T. (2011). Laxative activity of aqueous root extract of *Cnestis ferruginea* (Vahl ex DC) in loperamide-induced constipated rats. *Nigerian Journal of Gastroenterology and Hepatology*, 3(1-2), 21-29.
- Yakubu, M.T. and Adams, M.D. (2025). HPLC profile, biochemical and histoarchitectural changes in loperamide-induced constipated Wistar rats after oral administration of aqueous extract of *Cnestis ferruginea* (Vahl ex DC) roots. *Pharmacological Research - Natural Products*, 6, 100144. <https://doi.org/10.1016/j.prenap.2025.100144>.
- Zhou, J.F., Lou, J.G., Zhou, S.L. and Wang, J.Y. (2025). Potential oxidative stress in children with chronic constipation. *World Journal of Gastroenterology*, 11(3), 368-371. doi: 10.3748/wjg.v11.i3.368.