



Lactogenic Effects of Traditional Cereal-based Diets on Neonatal Development in Wistar rats

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ABSTRACT

OBJECTIVES: This study evaluated the effects of maternal consumption of five natural galactagogues: *Zea mays*, *Eleusine coracana*, *Panicum miliaceum*, and *Pennisetum glaucum* on growth and metabolic outcomes in suckling Wistar rat pups. **METHODOLOGY:** Sixty pregnant Wistar rats were allowed to deliver. After parturition, the dams were randomly assigned to control and experimental groups and were all given normal rat chow and water. Besides that, the dams in the experimental groups received 100g/kg/day of yellow *Zea mays*, white *Zea mays*, *Pennisetum glaucum*, *Eleusine coracana*, and *Panicum miliaceum* respectively and a group was also administered metoclopramide (5mg/kg/day), a pharmacological galactagogue. The administrations began from postnatal day 2 (PND 2) and lasted the period of lactation. Developmental milestones were tracked, and lipid and protein profiles were analyzed in brain, serum, and liver samples from male and female pups using GraphPad Prism, with results expressed as mean \pm SEM.

RESULTS: Results showed that all cereal diets affected developmental milestones, milk yield and body weight, with *Eleusine coracana*, yellow *Zea mays*, and *Pennisetum glaucum* demonstrating particularly notable improvements in lactation, lipid metabolism, and protein synthesis.

CONCLUSION: In conclusion, cereal preparations from *Zea mays*, *Eleusine coracana*, *Panicum miliaceum*, and *Pennisetum glaucum* enhanced lactation, improved infant growth, and influenced metabolism. Notably, *Eleusine coracana*, Yellow *Zea mays*, and *Pennisetum glaucum* emerged as the most impactful in these areas.

KEYWORDS: Lactation, *Zea mays*, *Eleusine coracana*, *Panicum miliaceum*, *Pennisetum glaucum*, infant growth

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INTRODUCTION

Breastfeeding is universally recognized as the optimal standard for infant nutrition, providing a uniquely balanced source of essential nutrients, immunological protection, and bioactive factors that are crucial for infant growth, immune development, and cognitive maturation.^{1,2} The World Health Organization (WHO) recommends exclusive breastfeeding for the first six months of life, followed by continued breastfeeding alongside complementary foods for up to two years or beyond. Despite these recommendations and the well-documented benefits, challenges related to lactation persist globally, with insufficient breast milk production being one of the most frequently reported concerns among new mothers.

In low- and middle-income countries (LMICs), like Nigeria, this issue is particularly prevalent, with studies indicating that up to 90% of women report concerns about inadequate milk supply during the postpartum period.^{3,4} This insufficiency can contribute to serious neonatal consequences, including hypoglycemia, poor weight gain, dehydration, and failure to thrive. These conditions not only jeopardize infant health but also contribute to increased morbidity and mortality rates.

In response to this issue of insufficient milk production, many lactating women turn to galactagogues. Galactagogues are substances that are believed to stimulate or increase breast milk production. These can be synthetic, such as domperidone and metoclopramide, or derived from natural sources, including a wide array of traditional herbs and food-based remedies.⁵ Among the commonly used botanical galactagogues, herbs like

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Trigonella foenum-graecum (fenugreek) and Silybum marianum (milk thistle) have shown some clinical promise in enhancing lactation through mechanisms such as prolactin stimulation and improved mammary gland function.^{6,7}

In addition to herbs, cereal grains have gained recognition in many cultures for their lactogenic properties. Traditional diets across Asia and Africa, for instance, incorporate grains such as Zea mays (maize), Eleusine coracana (finger millet), Panicum miliaceum (proso millet), and Pennisetum glaucum (pearl millet) during the postpartum period. These cereals are rich in complex carbohydrates, dietary fiber, amino acids, vitamins, minerals (such as calcium, iron, and zinc), and a variety of bioactive phytochemicals. Emerging evidence suggests that these nutritional components not only support maternal health and recovery but may also enhance milk production through their metabolic and endocrine effects to assist infant growth and development.^{8,10} However, while the traditional use of these cereals as galactagogues is well established, there is a paucity of scientific studies that evaluate their direct influence on lactation outcomes, particularly in terms of measurable benefits for infant growth and development. Most existing literature focuses on maternal perspectives or milk yield, with limited data on the biochemical or physiological impact on the nursing offspring. Therefore, the present study aims to bridge this gap by systematically evaluating the galactagogue effects of selected cereal preparations on lactating mothers and their suckling pups. Specifically, it investigates how maternal consumption of these cereal-based diets affects milk production and correlates with the growth parameters and metabolic profiles of the offspring. Understanding these interactions will provide a scientific basis for the inclusion of specific grains in maternal diets and contribute to evidence-based strategies for improving lactation and infant health, particularly in resource-limited settings.

METHODOLOGY

The cereals were all identified at the Department of Botany, University of Lagos. The conventional processing procedure was used. Briefly, the cereal grains were cleaned and fermented for 72 hours. An attrition mill was then used to wet-mill the fermented grains. To create the ogi slurry, the slurry was run through a muslin cloth, the chaff was taken out, and the filtrate was left to settle for twenty-four hours.¹¹ The ogi slurry was poured onto the muslin cloth and compressed to extract the water to make the ogi cake. The ogi cake was refrigerated at a temperature of 50°F until it was ready for use. Each cereal used was taken through this process, respectively.

Fifty-six (56) pregnant Wistar rats weighing (170-200g) were obtained from the animal care facility of the College of Medicine

of the University of Lagos and were used for this study. The sample size (n=56 pregnant Wistar rats) was determined based on similar experimental designs, which demonstrated sufficient power to detect significant differences in lactation outcomes. Although no formal power analysis was performed, our sample size is in line with previously published studies. Healthy, adult pregnant Wistar rats (8–10 weeks old, average weight 200–250 g). Rats with congenital abnormalities, illness, or those that failed to conceive after mating. The animals were kept in plastic cages in the animal care facility and fed with standard rat feed from Funsab Enterprises, Agege, Lagos. The animals were kept at a controlled temperature (29±2°C), with a controlled 12-hour light/dark cycle and acclimatized for two weeks before the experiment commenced. The female rats were mated with males of the same strain. The detection of a vaginal plug confirmed mating, and this day was denoted as Day 1. The pregnant dams were allowed to deliver. After parturition, the dams were randomly assigned to experimental groups to ensure balanced distribution. The dams were given different diets from postnatal day 2 (PND 2) as follows:

- Control: was fed with normal rat chow and water
- Metoclopramide: was fed with normal rat chow and administered 5mg/kg/day Metoclopramide [¹²].
- Zea mays; ZMy: was fed with normal rat chow and administered 100g/kg/day yellow maize (Zea mays)
- ZMw: was fed with normal rat chow and administered 100g/kg/day white maize (Zea mays)
- PG: was fed with normal rat chow and administered 100g/kg/day Pearl millet (Pennisetum glaucum)
- EC: was fed with normal rat chow and administered 100g/kg/day Finger millet (Eleusine coracana)
- PM : was fed with normal rat chow and administered 100g/kg/day Proso millet (Panicum miliaceum)

The administration lasted the period of lactation. All animal experiments complied with the ARRIVE guidelines and were carried out in accordance with the U.K. Animals (Scientific Procedures) Act, 1986 and associated guidelines, EU Directive 2010/63/EU for animal experiments.

The pups' developmental landmarks were observed throughout the study, focusing on key milestones such as eye opening, fur development, and pinna detachment. These markers provided insights into the effects of the treatments on early growth.

On postnatal day 36, pups were euthanized humanely, and blood was collected from the retro-orbital sinus for serum analysis. Brain, liver, adipose tissues, testes and ovaries were carefully excised and weighed.

The livers were immediately collected after death and briefly

Cereals	Moisture	Protein	Fat	Fibre	Ash	Carbohydrates (starch)
Yellow Zea mays (A)	10.29±0.017	1.16±0.147	0.60±0.010	2.07±0.067	3.22±0.013	82.71±0.040
White Zea mays (B)	9.84±0.013	1.31±0.000	0.46±0.006	4.23±0.050	3.60±0.017	80.76±0.267
Pennisetum glaucum (C)	11.24±0.030	2.19±0.000	0.74±0.010	3.25±0.027	2.87±0.023	79.71±0.010
Eleusine coracana (D)	8.27±0.020	2.63±0.000	0.86±0.013	4.64± 0.006	3.78±0.006	79.83±0.020
Panicum millaceum (E)	10.80±0.20	1.45±0.143	0.74±0.013	3.26±0.133	3.21±0.010	80.54±0.006

Table 1: Proximate composition (%) of samples of cereal varieties used. Mean ± Standard Deviation

rinsed in ice-cold saline and prepared for homogenization (10% w/v) in 50 mM cold potassium phosphate (pH 7.4). Tissue homogenates were centrifuged at 12,000 rpm at 4 °C for 15 minutes and the supernatants were stored at -80 °C for assessing the lipid and protein markers.

The brain homogenates (10%) in physiological saline were prepared using an homogenizer. After homogenization, brain homogenates were centrifuged for 10 min at 3000g. The supernatants were used for biochemical analysis. Lipid profile variables, total cholesterol, triacylglycerol (TAG), and high-density lipoprotein cholesterol (HDL-C) were measured using commercial kits (Randox Laboratory Ltd, Crumlin, Co. Antrim, UK). Low-density lipoprotein cholesterol (LDL-C) concentration was estimated (Friedewald et al., 1972), $LDL-C = TC - (HDL-C) - (TAG/5)$. Protein concentrations in serum, brain, and liver samples were determined at 540 nm by the procedure of.¹³

At 07:00 am, the weight (W1) of the pups was taken after spending the previous night with the dams. Then they were immediately isolated from the lactating dams for 4 hours. At 11:00 am, they were again weighed (W2) and returned to their dams for a one-hour breastfeeding period. The third weighing (W3) was determined at 12:00 noon to obtain the amount of milk consumed by the pups.

This method estimates milk yield ingested by the pups. This method calculates the difference in the weight of pups before and after feeding period. Weight gained are the amount of milk ingested by the pups. During each feeding period however, the use of the ingested milk for production of energy for movement and respiration in the pups is taken into consideration. The milk yield is thus evaluated by analyzing the correlation coefficient of the weight loss. The formula below was used to calculate milk yield:

$$\text{Milk yield (g)} = (W3 - W2) + [(W2 - W1) / 4]$$

where:

- W3 - W2 represents the weight gain of the pups after lactation.
- [(W2 - W1) / 4] represents the correlation coefficient of weight loss.¹²

Data were analyzed using GraphPad Prism, with results expressed as mean ± SEM. Group comparisons were conducted

using two-way ANOVA, followed by Tukey's post-hoc test. Statistical significance was considered at $p < 0.05$, with further distinctions at lower significance thresholds.

RESULTS

Table 1 shows the proximate composition of the cereal varieties used in the study with each component highlighted in terms of moisture, protein, fat and fiber content as well as ash and carbohydrate composition.

SERUM CHOLESTEROL

In the male pups, groups exposed to metoclopramide, Zea mays (white), Pennisetum glaucum, and Eleusine coracana had lower cholesterol levels when compared to the control, while those in the Panicum miliaceum group had higher levels when compared to the control. Zea mays (yellow) and Panicum miliaceum exposed groups had higher cholesterol levels when compared to the metoclopramide group, whereas Zea mays (white), Pennisetum glaucum, and Eleusine coracana had lower levels when compared to the metoclopramide group.

In the female pups, all experimental groups had lower cholesterol levels when compared to the control, with Zea mays (white), Eleusine coracana, and Panicum miliaceum also showing reductions when compared to the metoclopramide group.

Within groups, males in the control and Metoclopramide groups had lower cholesterol levels when compared to the female pups, while Eleusine coracana and Panicum miliaceum male pups had higher cholesterol levels when compared to their female counterparts.

HEPATIC CHOLESTEROL

Hepatic cholesterol level increased in the male metoclopramide group, but it was decreased in Zea mays (yellow), Zea mays (white), Pennisetum glaucum, Eleusine coracana, and Panicum miliaceum when compared to the control male pups. In the female pups, hepatic cholesterol level was higher in all experimental groups when compared to the control but it was lower in Zea mays (yellow), Pennisetum glaucum, Eleusine coracana, and Panicum miliaceum when compared to the metoclopramide group.

Within groups, males in the control, Pennisetum glaucum, and

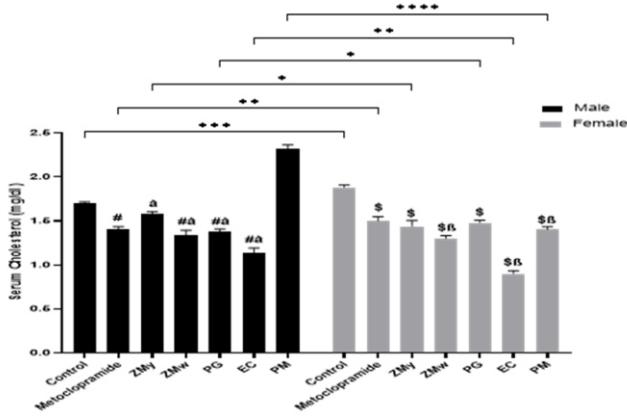


Fig 1: Lactogenic effect of cereal preparations on serum cholesterol in male and female pups. Values are expressed as mean \pm SD. $P < 0.05^*$, 0.01^{**} , 0.001^{***} , 0.0001^{****} vs female. $\#p < 0.05$ vs Control male; $\hat{a}p < 0.05$ vs Metoclopramide Male; $\$p < 0.05$ vs Control female; $\beta p < 0.05$ vs Metoclopramide female. ZMy = yellow maize (*Zea mays*); ZMw = white maize (*Zea mays*); PG = Pearl millet (*Pennisetum glaucum*); EC = Finger millet (*Eleusine coracana*); PM = Proso millet (*Panicum miliaceum*)

Panicum miliaceum groups had higher hepatic cholesterol levels when compared to the females, while males in the metoclopramide, *Zea mays* (yellow), *Zea mays* (white), and *Eleusine coracana* groups had lower levels when compared to the female pups.

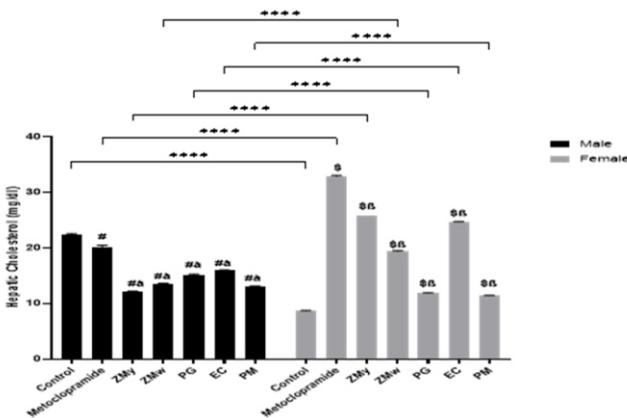


Fig 2: Lactogenic effect of cereal preparations on hepatic cholesterol in male and female pups. Values are expressed as mean \pm SD. $P < 0.05^*$, 0.01^{**} , 0.001^{***} , 0.0001^{****} vs female. $\#p < 0.05$ vs Control male; $\hat{a}p < 0.05$ vs Metoclopramide Male; $\$p < 0.05$ vs Control female; $\beta p < 0.05$ vs Metoclopramide female. ZMy = yellow maize (*Zea mays*); ZMw = white maize (*Zea mays*); PG = Pearl millet (*Pennisetum glaucum*); EC = Finger millet (*Eleusine coracana*); PM = Proso millet (*Panicum miliaceum*)

BRAIN CHOLESTEROL

Brain cholesterol level was higher in the male pup groups exposed to *Zea mays* (yellow), *Eleusine coracana*, and *Panicum miliaceum* but lower in those exposed to *Zea mays* (white), *Pennisetum glaucum*, and metoclopramide compared to the control male pups. In the female pup groups, brain cholesterol level increased in the metoclopramide, *Zea mays* (yellow), *Pennisetum glaucum*, *Eleusine coracana*, and *Panicum miliaceum* groups but decreased in *Zea mays* (white) when compared to the control female pups. The cholesterol level was higher in *Zea mays* (yellow) and *Eleusine coracana* but lower in *Zea mays* (white) and *Panicum miliaceum* when compared to the metoclopramide female group.

Within groups, males in the metoclopramide, *Zea mays* (yellow), *Pennisetum glaucum*, and *Eleusine coracana* exposed groups had lower brain cholesterol when compared to the female pups, while male pups in the *Zea mays* (white) and *Panicum miliaceum* groups had higher brain cholesterol levels when compared to their female counterparts.

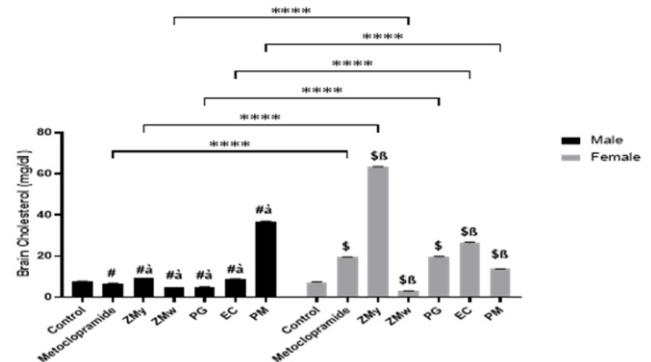


Fig 3: Lactogenic effect of cereal preparations on brain cholesterol in male and female pups. Values are expressed as mean \pm SD. $P < 0.05^*$, 0.01^{**} , 0.001^{***} , 0.0001^{****} vs female. $\#p < 0.05$ vs Control male; $\hat{a}p < 0.05$ vs Metoclopramide Male; $\$p < 0.05$ vs Control female; $\beta p < 0.05$ vs Metoclopramide female. ZMy = yellow maize (*Zea mays*); ZMw = white maize (*Zea mays*); PG = Pearl millet (*Pennisetum glaucum*); EC = Finger millet (*Eleusine coracana*); PM = Proso millet (*Panicum miliaceum*)

SERUM TRIGLYCERIDE

In the male pups, all groups had higher triglyceride levels when compared to the control, while *Panicum miliaceum* group had higher serum triglyceride level when compared to the metoclopramide group. In the female pups, all groups had lower levels when compared to the control, except for *Zea mays* (yellow), which had higher triglyceride level when compared to the metoclopramide group. The female pups exposed to *Zea mays* (white) and *Panicum miliaceum* had lower triglyceride levels when compared to the metoclopramide group.

Within groups, triglyceride levels were higher in the males when

compared to the female pups in the metoclopramide, Zea mays (white), Pennisetum glaucum, Eleusine coracana, and Panicum miliaceum groups, while the male control and Zea mays (yellow) groups had lower levels of triglyceride when compared to their female counterparts.

HEPATIC TRIGLYCERIDE

Hepatic triglyceride levels increased in the male groups exposed to Zea mays (yellow) and Panicum miliaceum but decreased in those exposed to Zea mays (white) when compared to the control male pups. The hepatic triglyceride levels in the Zea mays (yellow) and Panicum miliaceum exposed male groups were also higher than the metoclopramide group, while the hepatic triglyceride level in the Zea mays (white) group was lower when compared to the metoclopramide male group. In the females, hepatic triglyceride levels were higher in the metoclopramide, Zea mays (yellow), Pennisetum glaucum, and Eleusine coracana groups exposed groups when compared to the control. The Zea mays (yellow), Pennisetum glaucum, and Eleusine coracana exposed groups also had higher levels of hepatic triglyceride levels when compared to the metoclopramide group, while Zea mays (white) and Panicum miliaceum groups had lower levels when compared to the metoclopramide female group.

Within groups, the male pups in the control and Panicum miliaceum groups had higher hepatic triglycerides when compared to the female pups, while the male pups in the metoclopramide and Pennisetum glaucum groups had lower levels than their female counterparts.

BRAIN TRIGLYCERIDE

The brain triglyceride level increased in the male groups exposed to metoclopramide, Eleusine coracana, and Panicum miliaceum but decreased in those exposed to Zea mays (yellow), Zea mays (white), and Pennisetum glaucum when compared to the control. The male pups of the Zea mays (yellow), Zea mays (white), and Pennisetum glaucum groups had lower triglyceride levels when compared to the metoclopramide group, while the male pups in the Panicum miliaceum group had higher brain triglyceride levels when compared to the metoclopramide group. In the females, the triglyceride levels were higher in the metoclopramide, Zea mays (yellow), Eleusine coracana, and Panicum miliaceum groups but lower in Zea mays (white) when compared to the control. The brain triglyceride levels were also higher in the Pennisetum glaucum, Eleusine coracana, and Panicum miliaceum exposed groups when compared to the Metoclopramide group, while the Zea mays (yellow) and Zea mays (white) exposed groups had lower brain triglyceride levels when compared to the metoclopramide group.

Within groups, triglyceride levels were higher in males when

compared to the females in the control, Metoclopramide, Zea mays (white), and Panicum miliaceum groups, while males in Pennisetum glaucum and Eleusine coracana had lower triglyceride levels when compared to their female counterparts.

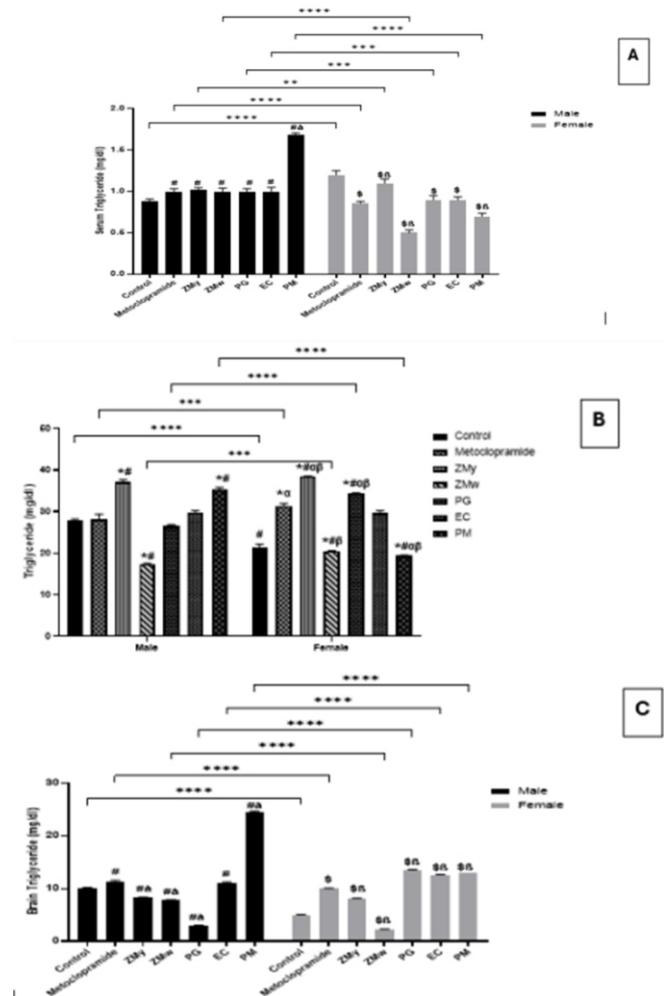


Fig 4A: Lactogenic effect of cereal preparations on serum triglyceride in male and female pups. **B:** Lactogenic effect of cereal preparations on hepatic triglyceride in male and female pups. **C:** Lactogenic effect of cereal preparations on brain triglyceride in male and female pups. Values are expressed as mean \pm SD. $P < 0.05^*$, 0.01^{**} , 0.001^{***} , 0.0001^{****} vs female. # $p < 0.05$ vs Control male; $\delta p < 0.05$ vs Metoclopramide Male; $\$ p < 0.05$ vs Control female; $\beta p < 0.05$ vs Metoclopramide female. ZMy = yellow maize (Zea mays); ZMw = white maize (Zea mays); PG = Pearl millet (Pennisetum glaucum); EC = Finger millet (Eleusine coracana); PM = Proso millet (Panicum miliaceum)

SERUM HDL

In males, groups exposed to metoclopramide, Zea mays (white), Pennisetum glaucum, and Eleusine coracana had lower HDL levels when compared to the control, while Zea mays (yellow)

and *Panicum miliaceum* had higher levels when compared to the control. *Zea mays* (yellow) and *Panicum miliaceum* also had increased serum HDL level when compared to the metoclopramide group, whereas *Eleusine coracana* exposed group had lower HDL levels when compared to the metoclopramide group.

In females, all experimental groups had lower HDL levels when compared to the control. *Zea mays* (white) and *Eleusine coracana* groups had lower levels, while *Pennisetum glaucum* and *Panicum miliaceum* had higher serum HDL levels when compared to the metoclopramide group.

Within groups, serum HDL levels were lower in females than males in the control, *Pennisetum glaucum*, and *Panicum miliaceum* groups. Conversely, females had higher HDL levels when compared to the males in the Metoclopramide, *Zea mays* (yellow), *Zea mays* (white), and *Eleusine coracana* groups.

HEPATIC HDL

Hepatic HDL increased in male groups exposed to metoclopramide and *Eleusine coracana* but decreased in those exposed to *Zea mays* (yellow) and *Pennisetum glaucum* when compared to the control. All male groups had lower HDL when compared to the metoclopramide group.

In the females, hepatic HDL was higher in the metoclopramide, *Zea mays* (yellow), *Zea mays* (white), *Eleusine coracana*, and *Panicum miliaceum* groups but lower in *Pennisetum glaucum* when compared to the control. *Zea mays* (white) and *Eleusine coracana* had higher HDL levels when compared to the metoclopramide group, while *Pennisetum glaucum* exposed group had lower HDL levels when compared to the metoclopramide group.

Within groups, hepatic HDL was higher in males than females in the control, *Pennisetum glaucum*, and *Panicum miliaceum* groups. However, the males had lower levels when compared to the females in the metoclopramide, *Zea mays* (yellow), *Zea mays* (white), and *Eleusine coracana* groups.

BRAIN HDL

Brain HDL level decreased in the male groups exposed to *Zea mays* (white) and *Pennisetum glaucum* but increased in those exposed to *Panicum miliaceum* when compared to the control. *Zea mays* (white) and *Pennisetum glaucum* exposed groups also had lower HDL levels when compared to the metoclopramide group, while *Panicum miliaceum* exposed group had higher levels of HDL when compared to the metoclopramide group.

In females, the brain HDL level was higher in the metoclopramide, *Zea mays* (yellow), *Pennisetum glaucum*, *Eleusine coracana*, and *Panicum miliaceum* groups but lower in *Zea mays* (white) group when compared to the control. *Zea*

mays (yellow), *Pennisetum glaucum*, *Eleusine coracana*, and *Panicum miliaceum* had higher levels of brain HDL when compared to the metoclopramide group, while *Zea mays* (white) had lower HDL levels of brain HDL when compared to the metoclopramide group.

Within groups, males had lower HDL levels when compared to the females in the control, metoclopramide, *Zea mays* (yellow), *Pennisetum glaucum*, and *Eleusine coracana* groups. The HDL level was however higher in males than females in *Panicum miliaceum* and *Zea mays* (white) groups

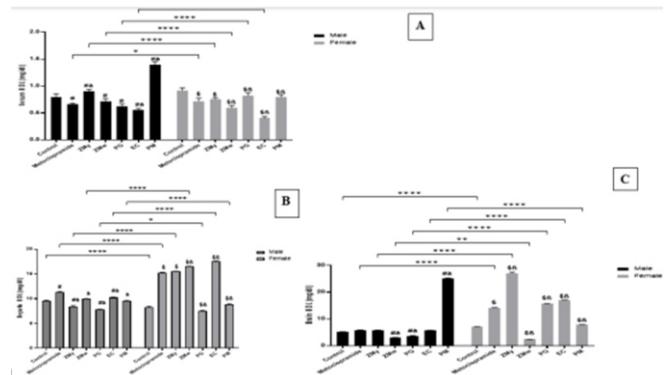


Fig 5A: Lactogenic effect of cereal preparations on serum HDL in male and female pups. **B:** Lactogenic effect of cereal preparations on hepatic HDL in male and female pups. **C:** Lactogenic effect of cereal preparations on brain HDL in male and female pups. Values are expressed as mean \pm SD. $P < 0.05^*$, 0.01^{**} , 0.001^{***} , 0.0001^{****} vs female. $\#p < 0.05$ vs Control male; $\hat{a}p < 0.05$ vs Metoclopramide Male; $\$p < 0.05$ vs Control female; $\beta p < 0.05$ vs Metoclopramide female. ZMy = yellow maize (*Zea mays*); ZMw = white maize (*Zea mays*); PG = Pearl millet (*Pennisetum glaucum*); EC = Finger millet (*Eleusine coracana*); PM = Proso millet (*Panicum miliaceum*)

SERUM LDL

In the males exposed to *Zea mays* (yellow), the LDL level was higher when compared to the control, while those exposed to *Panicum miliaceum* had lower levels of serum LDL when compared to the control. The LDL levels were higher in males exposed to *Zea mays* (yellow) and lower in those exposed to *Panicum miliaceum* when compared to the metoclopramide group,

All experimental groups in the females had lower LDL levels when compared to the control. Additionally, those exposed to *Zea mays* (white), *Eleusine coracana*, and *Panicum miliaceum* had lower LDL levels when compared to the metoclopramide group, while those exposed to *Pennisetum glaucum* showed an increase in LDL levels when compared to the metoclopramide group.

Within groups, LDL levels were lower in males exposed *Panicum miliaceum* than in their female counterparts. Similarly, the male control, *Pennisetum glaucum*, and *Panicum miliaceum* groups had lower LDL levels than their respective female groups. However, LDL levels were higher in males exposed to *Zea mays* (yellow), *Zea mays* (white), and *Eleusine coracana* when compared to their female counterparts.

HEPATIC LDL

Hepatic LDL levels were higher in males exposed to *Zea mays* (yellow), *Zea mays* (white), *Pennisetum glaucum*, and *Eleusine coracana* than in the control male pups. Those taking *Pennisetum glaucum* and *Eleusine coracana* also showed an increase in hepatic LDL levels when compared to the metoclopramide group, while those exposed to *Panicum miliaceum* had lower LDL levels than the metoclopramide group.

In females, hepatic LDL level increased in all experimental groups compared to the control. Additionally, those taking *Pennisetum glaucum* had higher LDL levels than the metoclopramide group, whereas those taking *Zea mays* (yellow), *Zea mays* (white), *Eleusine coracana*, and *Panicum miliaceum* had lower LDL levels than the metoclopramide group.

Within groups, hepatic LDL levels were lower in males exposed to metoclopramide than in their female counterparts. However, males taking *Zea mays* (white), *Pennisetum glaucum*, and *Eleusine coracana* had higher LDL levels than their female counterparts.

BRAIN LDL

Brain LDL increased in males exposed to metoclopramide, *Zea mays* (white), and *Panicum miliaceum* when compared to the control. Conversely, LDL levels decreased in males exposed to *Zea mays* (yellow), *Pennisetum glaucum*, and *Eleusine coracana* when compared to the control. All experimental male groups had lower brain LDL levels than the metoclopramide group.

In females, those exposed to *Pennisetum glaucum*, *Eleusine coracana*, and *Panicum miliaceum* showed increased LDL levels compared to the control, while those exposed to *Zea mays* (yellow) and *Zea mays* (white) had lower levels. Additionally, those taking *Pennisetum glaucum*, *Eleusine coracana*, and *Panicum miliaceum* had higher LDL levels than the metoclopramide group, while those taking *Zea mays* (yellow) and *Zea mays* (white) had lower levels than the metoclopramide group.

Within groups, LDL levels were higher in males than females in the control, metoclopramide, *Zea mays* (yellow), *Zea mays* (white), and *Panicum miliaceum* groups. In contrast, LDL levels were lower in males than in females in the *Pennisetum glaucum*

and *Eleusine coracana* groups.

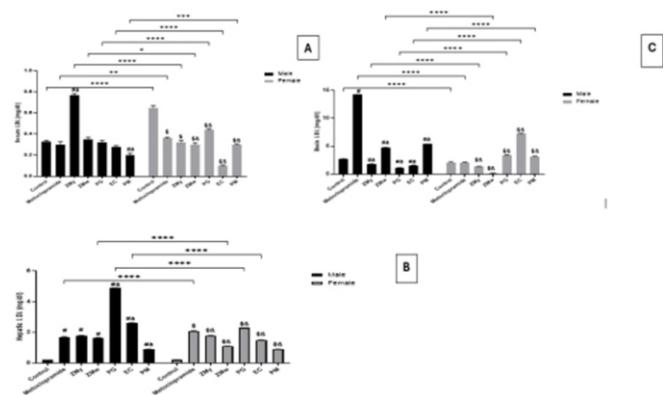


Fig 6A: Lactogenic effect of cereal preparations on serum LDL in male and female pups. **B:** Lactogenic effect of cereal preparations on hepatic LDL in male and female pups. **C:** Lactogenic effect of cereal preparations on brain LDL in male and female pups. Values are expressed as mean \pm SD. $P < 0.05^*$, 0.01^{**} , 0.001^{***} , 0.0001^{****} vs female. $\#p < 0.05$ vs Control male; $\hat{a}p < 0.05$ vs Metoclopramide Male; $\$p < 0.05$ vs Control female; $\beta p < 0.05$ vs Metoclopramide female. ZMy = yellow maize (*Zea mays*); ZMw = white maize (*Zea mays*); PG = Pearl millet (*Pennisetum glaucum*); EC = Finger millet (*Eleusine coracana*); PM = Proso millet (*Panicum miliaceum*)

SERUM TOTAL PROTEIN

In males, total protein significantly increased in the metoclopramide, *Zea mays* (yellow), *Zea mays* (white), *Pennisetum glaucum*, and *Panicum miliaceum* exposed groups when compared to the control, while *Eleusine coracana* showed a decrease when compared to the control. The total protein increased in *Zea mays* (white) and *Pennisetum glaucum* but decreased in *Zea mays* (yellow), *Eleusine coracana*, and *Panicum miliaceum* groups when compared to the metoclopramide group.

In females, *Zea mays* (yellow), *Zea mays* (white), and *Pennisetum glaucum* had higher total protein levels than the control, whereas the metoclopramide and *Panicum miliaceum* groups exhibited lower levels than the control. On the other hand, the total protein levels were higher in *Zea mays* (yellow), *Zea mays* (white), and *Pennisetum glaucum*, while *Eleusine coracana* and *Panicum miliaceum* showed a decrease when compared to the metoclopramide group.

Within groups, males in the control, *Zea mays* (yellow), and *Eleusine coracana* groups had lower total protein levels than their respective female counterparts. In contrast, the metoclopramide, *Pennisetum glaucum*, and *Panicum miliaceum* groups exhibited higher total protein levels in males than females.

HEPATIC TOTAL PROTEIN

Hepatic total protein levels significantly increased in male metoclopramide, Zea mays (white), Pennisetum glaucum, and Panicum miliaceum groups when compared to the control. The hepatic total protein decreased in male Zea mays (yellow), Zea mays (white), Pennisetum glaucum, and Eleusine coracana groups, while Panicum miliaceum showed an increase in hepatic total protein respectively when compared to the metoclopramide group.

In the females, the metoclopramide, Zea mays (white), and Eleusine coracana groups had higher hepatic total protein levels when compared to the control, while Zea mays (yellow), Pennisetum glaucum, and Panicum miliaceum showed a decrease. The total protein increased in Zea mays (white) and Eleusine coracana but decreased in the Zea mays (yellow), Pennisetum glaucum, and Panicum miliaceum groups when compared to the metoclopramide group.

Within groups, the hepatic total protein level was higher in males than females in the control, Zea mays (yellow), and Zea mays (white) groups. However, the hepatic total protein level was lower in males than the females in Pennisetum glaucum, Eleusine coracana, and Panicum miliaceum groups. Additionally, the male metoclopramide group had lower total protein levels than its female counterpart.

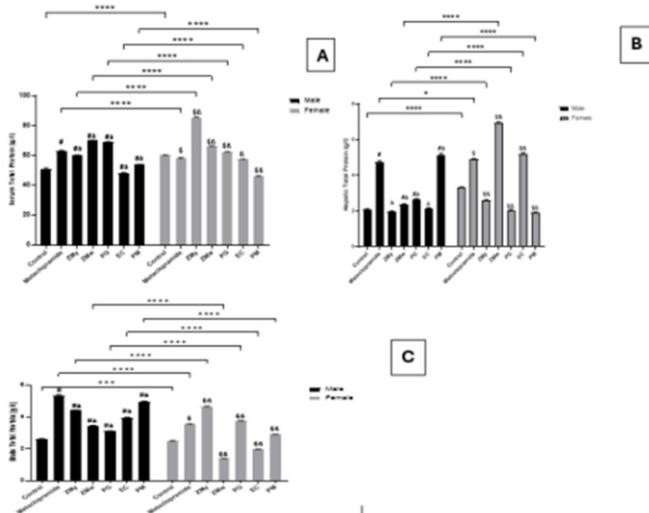


Fig 7A: Lactogenic effect of cereal preparations on serum total protein in male and female pups. **B:** Lactogenic effect of cereal preparations on hepatic total protein in male and female pups. **C:** Lactogenic effect of cereal preparations on brain total protein in male and female pups. Values are expressed as mean \pm SD. $P < 0.05^*$, 0.01^{**} , 0.001^{***} , 0.0001^{****} vs female. $\#p < 0.05$ vs Control male; $\hat{a}p < 0.05$ vs Metoclopramide Male; $\$p < 0.05$ vs Control female; $\beta p < 0.05$ vs Metoclopramide female. ZMY = yellow maize (Zea mays); ZMW = white maize (Zea mays); PG = Pearl millet

(Pennisetum glaucum); EC= Finger millet (Eleusine coracana); PM = Proso millet (Panicum miliaceum)

BRAIN TOTAL PROTEIN

Brain total protein levels increased in all male experimental groups when compared to the control. However, the total protein levels decreased in all male experimental groups when compared to the metoclopramide group.

In the females, brain total protein level increased in the metoclopramide, Zea mays (yellow), Pennisetum glaucum, and Panicum miliaceum groups when compared to the control, while Zea mays (white) and Eleusine coracana showed a decrease when compared to the control. The brain total protein levels increased in Zea mays (yellow) and Pennisetum glaucum but decreased in Zea mays (white), Eleusine coracana, and Panicum miliaceum when compared to the metoclopramide group.

Within groups, brain total protein was higher in males than females in the metoclopramide, Zea mays (white), Eleusine coracana, and Panicum miliaceum groups. Similarly, the male control group had higher total protein levels than the female control group. However, brain total protein levels were lower in males than females in Zea mays (yellow) and Pennisetum glaucum groups.

BRAIN WEIGHT

Brain weight was significantly reduced in male Pennisetum glaucum and Eleusine coracana groups compared to the male control group. Additionally, the male Pennisetum glaucum group had a significantly lower brain weight than the male pups in the metoclopramide group. In females, brain weight was significantly higher in Zea mays (yellow), Pennisetum glaucum, and Eleusine coracana groups compared to the female pups in the metoclopramide group.

Within-group comparisons showed that male control and Zea mays (yellow) groups had significantly higher brain weight than their female counterparts. Similarly, male pups in the metoclopramide and Zea mays (white) groups exhibited significantly greater brain weight than the corresponding female groups. In contrast, male Pennisetum glaucum and Panicum miliaceum groups showed significantly lower brain weight than their female counterparts.

LIVER WEIGHT

Liver weight was significantly lower in the male metoclopramide, Zea mays (white), Eleusine coracana, and Panicum miliaceum groups compared to the male control group. However, the male Pennisetum glaucum group showed a significant increase in liver weight relative to the control. Further comparisons indicated that liver weight was significantly higher in male Zea mays (yellow), Pennisetum

glaucum, and Eleusine coracana groups than in the male metoclopramide group.

In females, the liver weight was significantly increased in the metoclopramide, Zea mays (yellow), Zea mays (white), Pennisetum glaucum, and Eleusine coracana groups compared to the female control group, while the female Panicum miliaceum group exhibited a significant decrease compared to the female control group. Additionally, liver weight was higher in the female Zea mays (yellow), Zea mays (white), and Eleusine coracana groups compared to the female metoclopramide group, whereas it was significantly lower in the female Pennisetum glaucum and Panicum miliaceum groups.

Within-group analysis revealed that male control, Pennisetum glaucum, and Panicum miliaceum groups had significantly greater liver weight than their female counterparts, while the male pups in the metoclopramide, Zea mays (yellow), Zea mays (white), and Eleusine coracana groups exhibited significantly lower liver weight than the respective female groups.

ADIPOSE TISSUE WEIGHT

A significant increase in adipose tissue weight was observed in the male Zea mays (yellow) group when compared to the male control group. Conversely, the male Eleusine coracana and Panicum miliaceum groups exhibited significantly lower adipose tissue weight when compared to the male control group. The male Zea mays (yellow) group also had a significantly higher adipose tissue weight than the male pups in the metoclopramide group, whereas the male Zea mays (white) and Panicum miliaceum groups displayed significantly lower values than the male pups in the metoclopramide group.

In females, adipose tissue weight was significantly lower in the metoclopramide, Zea mays (yellow), Zea mays (white), Pennisetum glaucum, Eleusine coracana, and Panicum miliaceum groups compared to the female control group. Further comparisons showed that the female Zea mays (white), Pennisetum glaucum, and Panicum miliaceum groups had significantly lower adipose tissue weight than the female pups in the metoclopramide group.

Within-group analysis revealed significantly higher adipose tissue weight in the male Zea mays (white) and Pennisetum glaucum groups compared to their female counterparts, with a similar trend observed in the male Zea mays (yellow) group.

TESTES WEIGHT

Testes weight was significantly lower in the metoclopramide, Zea mays (yellow), Zea mays (white), Pennisetum glaucum, Eleusine coracana, and Panicum miliaceum groups when compared to the control group. Additionally, the Zea mays (white) and Panicum miliaceum groups exhibited significantly lower testes weight than the metoclopramide group.

OVARIAN WEIGHT

There were no differences in ovarian weight across all groups.

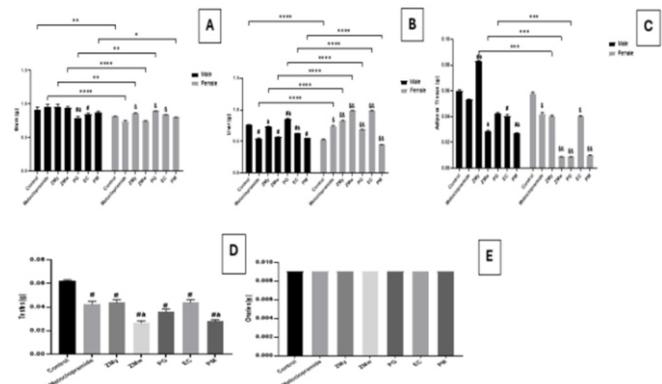


Fig 8A: Lactogenic effect of cereal preparations on brain weight in male and female pups. **B:** Lactogenic effect of cereal preparations on hepatic weight in male and female pups. **C:** Lactogenic effect of cereal preparations on adipose tissue weight in male and female pups. **D:** Lactogenic effect of cereal preparations on testis weight in male pups. **E:** Lactogenic effect of cereal preparations on weight of ovaries in female pups. Values are expressed as mean \pm SD. $P < 0.05^*$, 0.01^{**} , 0.001^{***} , 0.0001^{****} vs female. $\#p < 0.05$ vs Control male; $\hat{a}p < 0.05$ vs Metoclopramide Male; $\$p < 0.05$ vs Control female; $\beta p < 0.05$ vs Metoclopramide female. ZMy = yellow maize (Zea mays); ZMw = white maize (Zea mays); PG = Pearl millet (Pennisetum glaucum); EC = Finger millet (Eleusine coracana); PM = Proso millet (Panicum miliaceum)

DEVELOPMENTAL LANDMARKS

EYE OPENING

The onset of eye opening was delayed in the pups in the Panicum miliaceum group when compared to the control and Pennisetum glaucum groups, respectively.

FUR GROWTH

There was a delay in the fur appearance in the pups in the Panicum miliaceum group compared to the pups in the control, Zea mays (white) and Pennisetum glaucum groups.

PINNA DETACHMENT

The onset of pinna detachment was earlier in the metoclopramide, Zea mays (yellow), Zea mays (white), Pennisetum glaucum, and Eleusine coracana groups compared to the control group. However, the onset of pinna detachment the Zea mays (yellow) and Panicum miliaceum groups was delayed to pinna detachment when compared to the metoclopramide group. Conversely, the onset of pinna detachment of the Pennisetum glaucum group was earlier when compared to the metoclopramide group.

The onset of pinna detachment was earlier in the Zea mays (white), Pennisetum glaucum, and Eleusine coracana groups when compared to the Zea mays (yellow) group. Additionally, the onset of pinna detachment was delayed in the Eleusine coracana and Panicum miliaceum groups when compared to the Pennisetum glaucum group. Finally, the onset of pinna detachment was delayed in the Panicum miliaceum group when compared to the Zea mays (white) and Pennisetum glaucum groups.

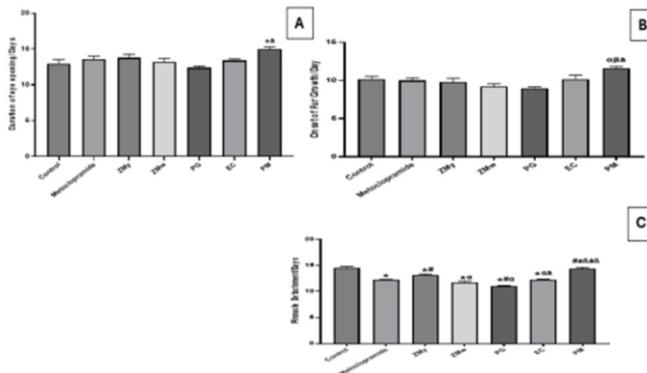


Fig 9A: Lactogenic effect of cereal preparations on day of eye opening in male and female pups. **B:** Lactogenic effect of cereal preparations on day of appearance of fur growth in male and female pups. **C:** Lactogenic effect of cereal preparations on pinna detachment in male and female pups. Values are expressed as mean \pm SD. $P < 0.05^*$, 0.01^{**} , 0.001^{***} , 0.0001^{****} vs female. $\#p < 0.05$ vs Control male; $\hat{a}p < 0.05$ vs Metoclopramide Male; $\$p < 0.05$ vs Control female; $\beta p < 0.05$ vs Metoclopramide female. ZMy = yellow maize (Zea mays); ZMw = white maize (Zea mays); PG = Pearl millet (Pennisetum glaucum); EC = Finger millet (Eleusine coracana); PM = Proso millet (Panicum miliaceum)

LACTATIONAL PERFORMANCE

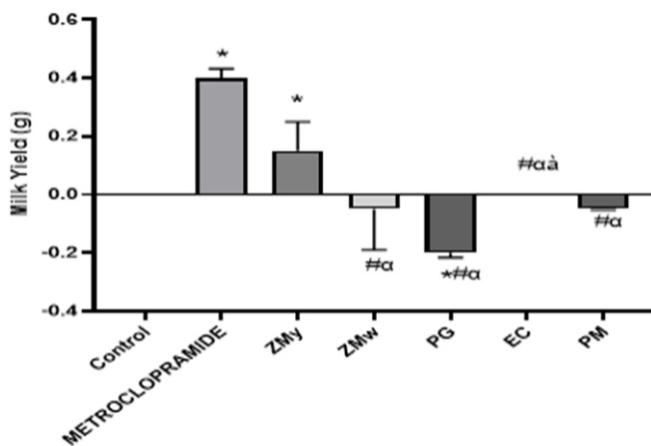


Fig 10: Lactogenic effect of cereal preparations on milk yield translating to body weight of male and female pups. Values are

expressed as mean \pm SD. $P < 0.05^*$, 0.01^{**} , 0.001^{***} , 0.0001^{****} vs female. $\#p < 0.05$ vs Control male; $\hat{a}p < 0.05$ vs Metoclopramide Male; $\$p < 0.05$ vs Control female; $\beta p < 0.05$ vs Metoclopramide female. ZMy = yellow maize (Zea mays); ZMw = white maize (Zea mays); PG = Pearl millet (Pennisetum glaucum); EC = Finger millet (Eleusine coracana); PM = Proso millet (Panicum miliaceum)

Metoclopramide and Zea mays (yellow) groups exhibited a significant increase in milk production when compared to the control group. In contrast, the Pennisetum glaucum group showed a significant reduction in milk yield relative to the control.

The milk yield was significantly lower in the Zea mays (white), Pennisetum glaucum, Eleusine coracana, and Panicum miliaceum groups when compared to the metoclopramide group. Similarly, Zea mays (white), Pennisetum glaucum, Eleusine coracana, and Panicum miliaceum groups demonstrated a significant decline in milk production when compared to the Zea mays (yellow) group.

Furthermore, the Eleusine coracana group had a significantly higher milk yield compared to the Pennisetum glaucum group.

DISCUSSION

Galactagogues enhance lactation, ensuring optimal growth in suckling pups.^{14,15} Maternal nutrition plays a crucial role in this process, with traditional herbal remedies often utilized despite varying scientific evidence.¹⁶ This study examined the lactation benefits of traditional cereals—Zea mays (maize), Eleusine coracana (finger millet), Panicum miliaceum (proso millet), and Pennisetum glaucum (pearl millet)—and their impact on offspring growth and metabolism.

Proximate analysis revealed distinct nutritional advantages among these cereals. Eleusine coracana exhibited the highest protein content (8.27%), essential for infant tissue development.¹⁷ Panicum miliaceum was rich in carbohydrates (70-75%) and essential minerals like iron and zinc, crucial for cognitive function and immunity.¹⁸ Zea mays, particularly yellow maize, provided a high energy source (82.71% carbohydrate) but had lower protein content (1.16%), making it less ideal as a sole dietary option.¹⁹

Total cholesterol levels decreased significantly in pups of mothers fed white Zea mays and Pennisetum glaucum, aligning with studies on high-fiber diets reducing cholesterol via bile acid excretion.²⁰ Phytosterols in these cereals likely contributed to this effect by competing with cholesterol for intestinal absorption.²¹ Similarly, previous studies have shown phytosterol-fed pups had lower cholesterol levels²², suggesting a potential long-term cardiovascular benefit.²³

Conversely, *Panicum miliaceum* increased triglyceride levels in both sexes, possibly due to its high riboflavin content (0.28 mg/100g), which promotes triglyceride synthesis.²⁴ However, female pups from white *Zea mays*-fed dams had reduced triglycerides, reinforcing maize's potential for lipid regulation.²⁵

Female pups showed increased HDL levels with yellow *Zea mays*, *Pennisetum glaucum*, and *Panicum miliaceum*, likely due to their high resistant starch content, which promotes SCFA production and improves lipid metabolism.²⁶ Soluble fiber in these cereals also traps cholesterol, preventing its reabsorption.²⁷ Carotenoids in yellow *Zea mays* (11.14 µg/g dry matter) further enhance HDL levels by reducing oxidative stress.²⁸ In contrast, male pups from *Pennisetum glaucum*-fed dams exhibited decreased HDL, potentially due to testosterone's negative association with HDL²⁹, while estrogen enhances HDL particle size and concentration.³⁰

The pups from *Panicum miliaceum* fed dams showed greater LDL reduction across brain, liver, and serum when compared to metoclopramide, suggesting its potential as a natural alternative to pharmaceutical galactagogues.³¹ *Zea mays* preparations also lowered LDL in female pups, consistent with studies linking fiber intake to improved lipid profiles.³²

Serum, liver, and brain protein levels increased in male pups from white *Zea mays*, *Pennisetum glaucum*, and *Panicum miliaceum*-fed dams. Female pups on white maize diets exhibited similar trends, emphasizing the role of these cereals in growth and development.³³

Pennisetum glaucum (9-21% protein) and *Panicum miliaceum* contain essential amino acids (leucine, methionine, and cysteine) necessary for protein biosynthesis.³⁴ Although *Zea mays* contains 8-11% protein, its high zein content limits essential amino acids like lysine and tryptophan, which are better supplied by albumin and globulin fractions.³⁵

Developmental markers like eye-opening and fur growth were largely unaffected, except in *Panicum miliaceum* pups, which showed delayed milestones. This suggests its nutritional profile influences developmental timing differently from other cereals. Testes size was affected across all cereal groups, but ovary size remained unchanged, aligning with research indicating female fertility is influenced by broader hormonal and environmental factors.³⁶ Liver and adipose tissue weights increased in pups of *Zea mays* and *Pennisetum glaucum*-fed dams, suggesting enhanced metabolic activity. Carotenoids in yellow maize may improve lipid metabolism and liver function by reducing oxidative stress.³⁷ Increased adipose tissue weight reflects enhanced lipid storage, possibly offering an advantage in energy-dense environments.³⁸

Brain weight increased in female pups but decreased in males

from *Pennisetum glaucum* and *Eleusine coracana* groups. This may be due to testosterone's influence on neuron differentiation, affecting nutrient utilization differently in males.³⁷ Female pups may allocate energy more efficiently toward neurodevelopment due to hormonal differences.³⁸ Metoclopramide and yellow *Zea mays* increased milk yield compared to the control group, with the former enhancing serum prolactin levels, a key hormone in lactation.³⁹

Yellow maize's higher carotenoid content, particularly lutein and zeaxanthin, may improve metabolic function, immune health, and reproductive performance, supporting higher milk production.^{40,41} Beta-carotene's role as a vitamin A precursor further enhances lactation outcomes.⁴² *Eleusine coracana* outperformed *Pennisetum glaucum* in milk yield, likely due to its superior calcium content (398 mg/100g vs. 42 mg/100g), which is essential for lactation and bone health.⁴³ Its higher phenolic and fiber content (15-22% vs. 11.3%) may also improve antioxidant properties and nutrient absorption, enhancing milk production.

CONCLUSION

In conclusion, This study demonstrates that cereal-based galactagogues, particularly *Eleusine coracana* and yellow *Zea mays*, enhanced lactation performance and improved pup growth in Wistar rats. These findings support their potential role as affordable dietary interventions for lactating mothers, warranting further clinical investigation. Cereal preparations from *Zea mays*, *Eleusine coracana*, *Panicum miliaceum*, and *Pennisetum glaucum* enhanced lactation, improved infant growth, and influenced metabolism. Notably, *Eleusine coracana*, Yellow *Zea mays*, and *Pennisetum glaucum* emerged as the most impactful in these areas. *Eleusine coracana* significantly improved lactation due to its high calcium and protein content, supporting maternal milk production and infant tissue development. Yellow *Zea mays*, rich in carotenoids, improved HDL levels and lipid metabolism, while also promoting infant growth through increased protein synthesis. *Pennisetum glaucum* effectively lowered cholesterol and supported protein biosynthesis, indicating cardiovascular and growth benefits. These effects vary by sex, suggesting hormonal interactions in nutrient processing. Despite their benefits, differences in metabolic responses highlight the need for further research to optimize maternal diets for long-term neonatal health.

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CONFLICT OF INTEREST

Author declared no conflict of interest

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AUTHORS CONTRIBUTIONS

OO: Conception, Design of the work, Data collection, and Drafting, Reviewed, Final approval, Agreement to be accountable.

JU: Conception, Design of the work, Acquisition, Data Analysis, and Drafting, Reviewed, Final approval, Agreement to be accountable.

DATA SHARING POLICY

The data that support the findings of this study are available from the corresponding author upon reasonable request.



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