Scientific Research Publishing

Open Journal of Animal Sciences, 2026, 16(4), 499-514
https://www.scirp.org/journal/ojas
ISSN Online: 2161-7627
ISSN Print: 2161-7597

Effects of Dietary Supplementation with Madagascar Cardamom (*Aframomum angustifolium*) Seed and Clove (*Syzygium aromaticum*) Powders on Sperm Characteristics in Male Rabbits

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How to cite this paper: Issa Abdel Djalil, O., Tchoffo, H., Dobgima, A.B., Tchouala, T.T., Djonko, D.C. and Ngoula, F. (2026) Effects of Dietary Supplementation with Madagascar Cardamom (*Aframomum angustifolium*) Seed and Clove (*Syzygium aromaticum*) Powders on Sperm Characteristics in Male Rabbits. *Open Journal of Animal Sciences*, **16**, 499-514.
https://doi.org/10.4236/ojas.2026.164030

Received: September 21, 2026
Accepted: October 26, 2026
Published: October 29, 2026

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Abstract

In order to improve the sperm characteristics of local rabbits and promote the use of phytobiotics, an experimental study entitled "Effects of dietary supplementation with Madagascar cardamom (*Aframomum angustifolium*) seed and clove (*Syzygium aromaticum*) powders on sperm characteristics in male rabbits" was conducted at the Mange Lapin farm. Twenty male rabbits with a mean body weight of 2993 ± 290 g were randomly allocated to five groups and housed individually. Rabbits in treatment T0 received a basal diet without additives, whereas those in treatments T1, T2, T3, and T4 received diets supplemented with 0.5%, 1% *A. angustifolium* powder and 0.5%, 1% clove powder, respectively. Animals were fed every morning between 7:00 and 8:00 a.m., with a daily feed allowance of 130 g throughout the 8-week trial. Semen was collected before the start of the experiment, after one month of treatment, and after two months (end of the trial) to monitor changes in sperm characteristics. The lower inclusion level of *A. angustifolium* powder (0.5% per kg of feed) significantly ($p < 0.05$) increased semen volume compared with the control group. Semen pH recorded after two months suggested that supplementation with 0.5% *A. angustifolium* (T1) and clove at both inclusion levels helped maintain

a slightly alkaline seminal pH, which is generally favorable for sperm viability and motility. Semen color was not markedly affected by either additive, with milky white remaining the predominant color across treatments and sampling periods. Group T2 (1% *A. angustifolium*) showed the greatest sperm concentration after one month, whereas T4 (1% clove) exhibited the highest concentration after two months. The proportion of motile spermatozoa generally increased after two months in all groups, while the proportion of immotile spermatozoa decreased, with a significant reduction already evident after one month in some treatments (T1 and T4). Overall, incorporating *A. angustifolium* and clove powders at 1% of the diet enhanced sperm characteristics and may contribute to improved fertility in local rabbits.

Keywords

Sperm Characteristics, Clove, Madagascar Cardamom, Rabbit

1. Introduction

The success of a breeding program for males depends heavily on sperm quality, which is assessed based on ejaculate volume, sperm concentration, motility, viability, and morphology. Alterations in these parameters can compromise herd fertility and reduce production output. However, sperm function is sensitive to environmental, nutritional, and health factors. In rabbits, for example, heat stress has specifically been associated with decreased motility and density, as well as decreased overall sperm quality and increased sperm abnormalities [1] [2]. This vulnerability primarily stems from oxidative stress, which is an imbalance between the production of reactive oxygen species and the body's antioxidant defenses. This leads to membrane lipid peroxidation, protein damage, and sperm DNA impairment, thereby reducing spermatozoa's fertilizing potential [3]. Given these constraints, the use of natural plant-based additives is increasingly being considered as a strategy to improve male fertility. Several studies conducted in rabbits have shown that supplementation with natural compounds, particularly polyphenols or dietary antioxidants, can improve antioxidant status and certain sperm parameters [4] [5]. This approach is all the more relevant given that plant extracts often serve as an accessible source of bioactive molecules, while also addressing the need for more sustainable and less costly solutions.

In this context, Madagascar cardamom (also known as Longoza) and cloves are of particular interest. Generally classified as *Aframomum angustifolium* in the reviewed literature, Madagascar cardamom is a tropical Zingiberaceae plant whose seeds and extracts have demonstrated antioxidant, anti-inflammatory, skin-protective, and antimicrobial activities [6] [7]. Cloves (*Syzygium aromaticum*) are recognized as spices rich in phenolic compounds, particularly eugenol, which has powerful antioxidant and pharmacological properties [8].

The value of these resources is reinforced by the results already observed with

cloves in male rabbits. Adding clove oil to the diet of adult rabbits, for example, improved several physical characteristics of sperm and reduced certain markers of oxidative stress, suggesting a positive effect on reproductive function [9]. However, despite these promising results, data regarding these two spices, especially Madagascar cardamom, are limited, particularly in native rabbits raised under tropical conditions.

This justifies the purpose of the present study, which aims to evaluate the effect of incorporating Madagascar cardamom seed and clove powder into the diet of male rabbits on sperm characteristics.

2. Materials and Methods

2.1. Study Area and Period

The study was conducted at the Mange Lapin farm in Dschang, in the western part of Cameroon, from January to April 2026. The farm is located in Dschang. Dschang is situated between latitudes 5˚26'49" and 10˚0'57" North and between longitudes 10˚0'57" East and 10˚0'57" West. The region has a Cameroonian equatorial climate, characterized by a rainy season from mid-March to mid-November and a dry season from mid-November to mid-March. Precipitation ranges from 1500 to 2000 mm per year; the average temperature is 21˚C; and relative humidity ranges from 40% to 97% [10].

2.2. Animal Materials and Housing

Twenty male rabbits, aged 4 to 5 months, weighing between 2.5 and 3 kg, and of local Cameroonian breeds, were used for the experiment. They came from the Mange Lapin farm.

The animals were housed individually in galvanized metal wire cages. Each cage was equipped with a feeder and a drinking nipple connected to a 100-liter bucket for water supply, fed by a pump.

2.3. Plant Material

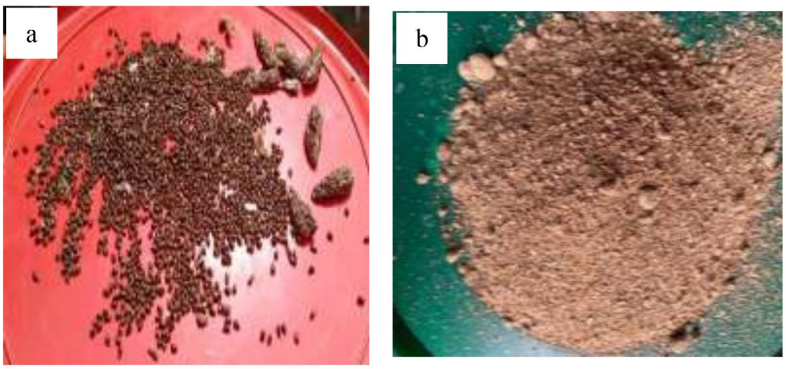


Figure 1. (a) Madagascar cardamom seeds; (b) Madagascar cardamom seed powder.

The Madagascar cardamom seeds (*Aframomum angustifolium*) (**Figure 1**) and

cloves (*Syzygium aromaticum*) (Figure 2) used in this study were collected in the town of Dschang. The seeds and cloves were dried and ground in a Moulinex blender. Then, 100 g of each powder was sent to the Laboratory of Biochemistry of Natural Substances at the University of Dschang for phytochemical analysis.

Figure 2. (a) Cloves; (b) Clove powder.

2.4. Phytochemical Analysis of Madagascar Cardamom Seeds and Cloves

Table 1 shows the phytochemical composition of powders made from Madagascar cardamom seeds and cloves.

Table 1. Results of the phytochemical analysis of powders made from Madagascar cardamom seeds and cloves.

Constituents	Madagascar cardamom seeds	Cloves
Alkaloids	+	−
Phenol	+	+
Flavonoids	+	+
Steroids and triterpenes	+	+
Terpenoids	−	+
Tannins	+	+
Saponins	−	+
Proteins	−	+
Carbohydrates	−	+
Mucilages	−	+
Anthocyanins	−	−
Anthraquinones	−	−

(+) present; (−) absent.

2.5. Diet and Experimental Design

The 20 rabbits were weighed, randomized, and divided into five groups of four rabbits each: the control group (T0) and the test groups (T1, T2, T3, and T4).

These animals were provided with water and a complete compound feed ad libitum (see Table 2). When formulating the diets, clove and Madagascar cardamom powders were added in varying amounts to the diets of the test groups. Once the diets were formulated, the feed was extruded into pellets to provide it to the rabbits in the form they prefer. The feed was provided at a rate of 135 g per day. For 60 days, the animals received one of the following treatments:

Group 1 (T0): base diet (control);

Group 2 (T1): T0 + 0.5% Madagascar cardamom powder;

Group 3 (T2): T0 + 1% Madagascar cardamom powder;

Group 4 (T3): T0 + 0.5% clove powder;

Group 5 (T4): T0 + 1% clove powder.

In this study, the rabbits were used exclusively for semen collection. The first collection was performed before the start of the trial, the second after one month of treatment, and the third after two months of treatment (end of the trial), in order to monitor changes in semen characteristics.

Table 2. Composition and bromatological characteristics of the rabbit diet.

Ingredients	Quantities (kg)
Corn	15
Wheat bran	60
Cotton seed meal	6
Soybean meal	6
Fish meal	4
CMAV 5%	4
Palm kernel meal	18
Shells	2
Total	115
Nutritional Composition	
Metabolizable Energy (kcal/kg DM)	2120.35
Crude protein (%/kg)	22.96
Crude fiber	10.815
Ca (%/kg)	1.50
P (%/kg)	1.12
Na (%/kg)	0.08
Lys (%/kg)	1.15
Meth (%/kg)	0.45

Ca: Calcium, P: Phosphorus, Na: Sodium, Lys: Lysine, Meth: Methionine.

2.6. Sperm Collection

Sperm was collected using an artificial vagina consisting of a hard plastic cylinder

containing a plastic sleeve filled with lukewarm water (42˚C) and lubricant, as well as a sterilized glass sperm collection tube at the other end. To collect the semen, a female decoy was placed in the male's cage for a few seconds to trigger the mating process. Then, just as the male attempted to mount her, the artificial vagina was slid under the female's abdomen toward her hindquarters, so that the opening was positioned in front of the male's penis. After intromission and ejaculation, the semen was transferred into a sterilized collection tube. Table 3 shows the sperm characteristics of determined before the start of the trial.

Table 3. Sperm characteristics of rabbits determined before the start of the trial.

Sperm characteristics	Values
Volume (µl)	691.88 ± 89.79
pH	7.58 ± 0.34
Color	Milky white semen
Density (10^6/ml)	189.04 ± 26.34
Motile SPZ (%)	46.17 ± 11.83
Rapidly progressive SPZ (%)	1.03 ± 0.66
Locally motile SPZ (%)	45.27 ± 9.51
Non-motile SPZ (%)	53.83 ± 15.15
Straight-line velocity of SPZ (µm/s)	3.05 ± 0.87
SPZ moving in a straight line (%)	9.10 ± 2.02
Live SPZ rate (%)	78.69 ± 25.82
Intact membrane rate (%)	88.34 ± 24.65
Normal SPZ rate (%)	89.00 ± 24.07

SPZ: Spermatozoa.

2.6.1. Semen Volume, pH, and Color

The volume of the collected ejaculate was assessed by direct visual reading of the graduations on the collection tube.

The pH of the semen was measured immediately after collection using a Sanxin pH meter.

The color of the ejaculate was determined by visual inspection of the semen in the transparent collection tube. The degree of color was scored on a scale of 0 to 3 according to the rabbit semen color determination scale cited by [11].

2.6.2. Individual Sperm Motility

To assess individual sperm motility, 10 µl of diluted semen was placed on a slide, a coverslip was placed over it, and observation was performed using the CASA (Computer-Assisted Sperm Analyzer) system. Four to five fields were analyzed at 10x magnification for each sample. This system also allowed for the assessment of sperm velocity.

2.6.3. Sperm Viability

To assess sperm viability, 10 µl of the solution prepared for motility testing was mixed with 10 µl of nigrosin and eosin, which were then applied and spread across the surface of the slide. Once the slide had dried on a 37˚C heating plate, observation was performed using the CASA system at 20x magnification. Out of a total of 200 counted spermatozoa, the percentage of live spermatozoa (appearing colorless) and dead spermatozoa (appearing dark) was determined for each slide.

2.6.4. Sperm Membrane Integrity

Sperm membrane integrity was assessed by adding 100 µl of diluted semen to 1000 µl of a hypoosmotic sucrose solution at 100 mOsmol/l, preheated to 37˚C. This mixture was then placed on a microscope slide after 60 minutes of incubation. A thick smear was prepared, dried on a heating stage at 37˚C, and then observed under an optical microscope at 400× magnification. Out of a total of 100 counted spermatozoa, the percentage of spermatozoa with intact plasma membranes and those with disintegrated plasma membranes was determined for each slide.

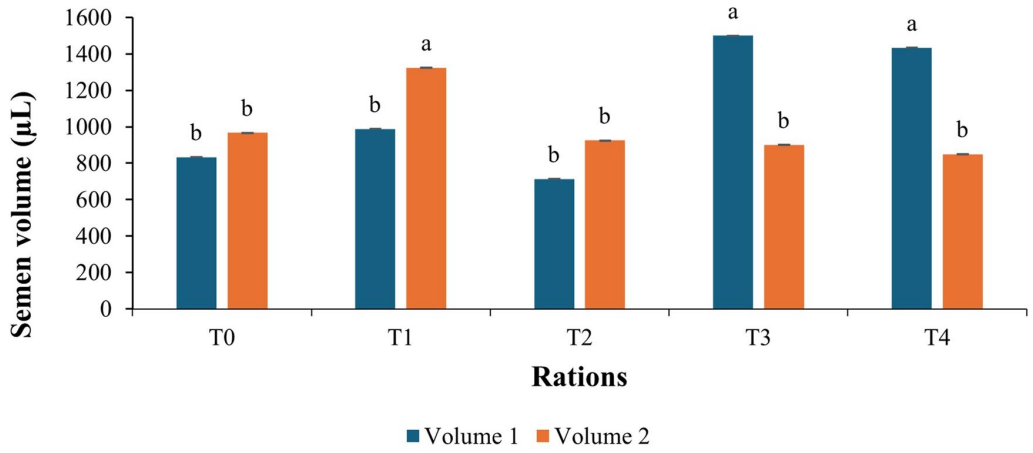
2.7. Statistical Analyses

Data for all parameters studied were entered and organized using Microsoft Excel 2019 and subsequently subjected to statistical analysis using SPSS version 25.0. A two-way analysis of variance (ANOVA) was performed to assess the effects of additive type and additive concentration, as well as their interaction, on the measured parameters. When significant differences were detected, means were separated using Duncan's multiple range test. Student's t-test was used to compare the values obtained during the two collection periods. Data are presented as means ± standard deviation (SD), and differences were considered statistically significant at a 5% significance level ($p < 0.05$).

3. Results

3.1. Effect of Madagascar Cardamom Seed Powder and Clove Powder on Rabbit Semen Volume

Figure 3 summarizes the effect of adding Madagascar cardamom seed powder and clove powder to the diet on rabbit semen volume. The results show that the addition of Madagascar cardamom seed powder, regardless of the rate, did not significantly affect ($p > 0.05$) sperm volume compared to the control group after one month of treatment. Furthermore, clove powder, at levels of 0.5% and 1% in the rabbit diet, resulted in comparable volumes, but significantly higher than those recorded in the control group, after one month of treatment. However, the semen volumes recorded after two months of treatment were comparable in animals fed diets containing Madagascar cardamom seed powder or clove powder, with the exception of the lowest concentration of Madagascar cardamom powder (0.5% per kg of feed), which resulted in a significantly ($p < 0.05$) higher sperm volume in the treated rabbits compared to those in the control group.

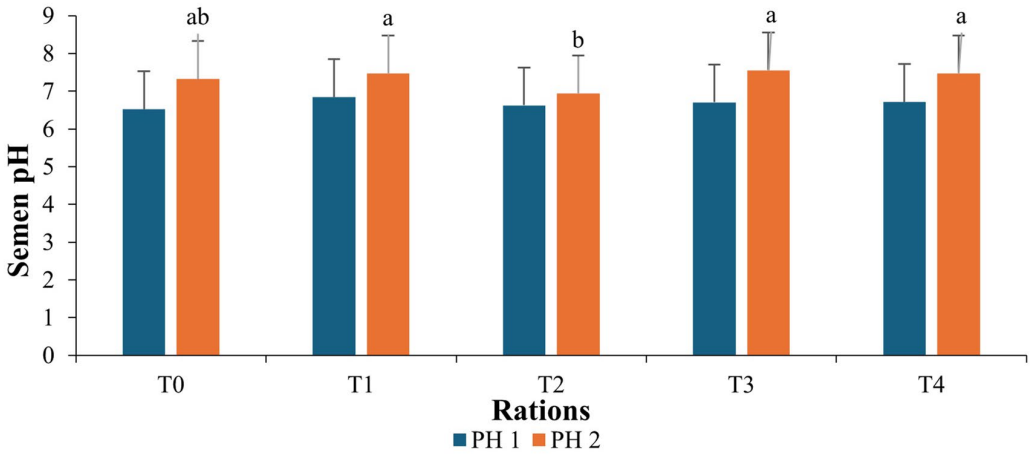


Volume 1: Semen volume after 1 month of treatment; **Volume 2:** Semen volume after 2 months of treatment; T0: control treatment; T1: 0.5% Madagascar cardamom; T2: 1% Madagascar cardamom; T3: 0.5% cloves; T4: 1% cloves; a, b: Histograms labeled with different letters for the same parameter are significantly different.

Figure 3. Effect of Madagascar cardamom seed powder and clove powder on rabbit semen volume.

3.2. Effect of Madagascar Cardamom Seed Powder and Clove Powder on Rabbit Semen pH

Figure 4 shows the effect of adding Madagascar cardamom seed powder and clove powder to the diet on rabbit semen pH. The results indicate that, after one month of treatment (pH1), semen pH values were similar across the different groups and did not differ significantly ($p > 0.05$) from the control group. Furthermore, after two months of treatment (pH2), an increase in pH was observed in animals that received 0.5% and 1% Madagascar cardamom, as well as in those that received 0.5% cloves, compared to the value recorded in the control group. However, this increase was not statistically significant.

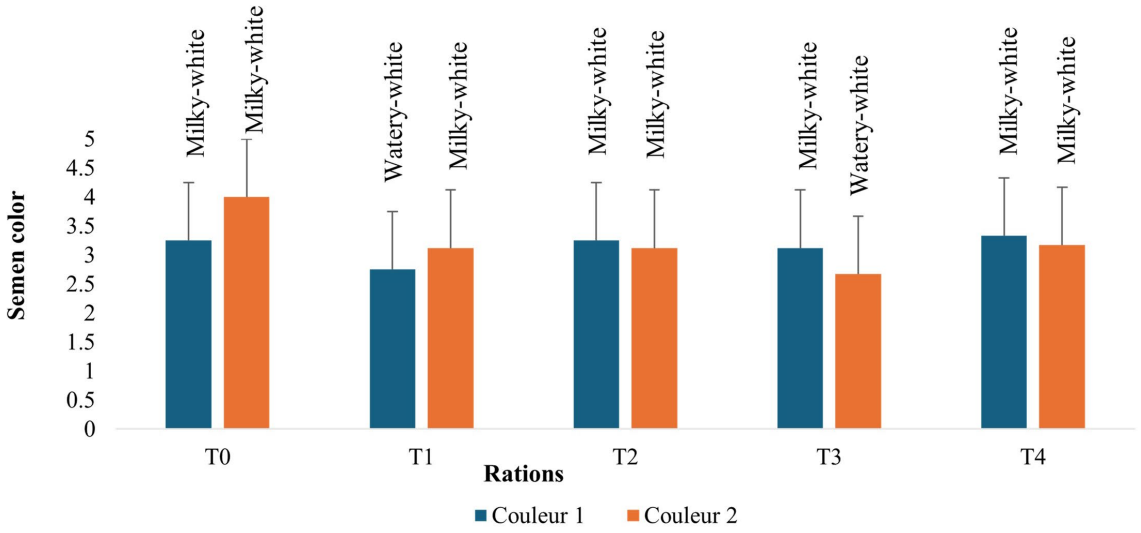


pH1: pH recorded after 1 month of treatment; **pH2:** pH recorded after 2 months of treatment; T0: control treatment; T1: 0.5% Madagascar cardamom; T2: 1% Madagascar cardamom; T3: 0.5% cloves; T4: 1% cloves; a, b: Histograms labeled with different letters for the same parameter are significantly different.

Figure 4. Effect of Madagascar cardamom seed powder and clove powder on rabbit semen pH.

3.3. Effect of Madagascar Cardamom Seed Powder and Clove Powder on the Color of Rabbit Semen

Figure 5 illustrates the effect of adding Madagascar cardamom seed powder and clove powder to the diet on the color of rabbit semen. The results show that after one month of treatment, the observed values correspond predominantly to a milky white color. The semen colors recorded in animals fed the diet containing 1% Madagascar cardamom and 1% cloves are identical to those of the control group (milky white). The diet containing 0.5% Madagascar cardamom resulted in a watery white color. After two months (color 2), the diets containing 0.5% and 1% Madagascar cardamom and 1% cloves showed a milky white color, similar to that of the control group.



Color 1: Semen color observed after 1 month of treatment; **Color 2:** Semen color observed after 2 months of treatment. T0: control treatment; T1: 0.5% Madagascar cardamom; T2: 1% Madagascar cardamom; T3: 0.5% cloves; T4: 1% cloves.

Figure 5. Effect of Madagascar cardamom seed powder and clove powder on rabbit semen color.

3.4. Effect of Madagascar Cardamom Seed Powder and Clove Powder on Sperm Density and Motility

Table 4 summarizes the effect of treatment duration and the addition of Madagascar cardamom seed powder and clove powder to the diet on sperm density and kinetic parameters. The results show that adding these powders to the rabbits' diet led to a significant ($p < 0.05$) increase in sperm density after one month of treatment. However, when considering only the rabbits fed diets containing the additives, sperm density was significantly ($p < 0.05$) higher in rabbits fed the diet containing the highest concentration (1%) of Madagascar cardamom. After two months of treatment, the sperm density values recorded in the groups treated with the additives-regardless of type and dose-were comparable to those of the control group.

When comparing only the animals fed diets containing both additives, sperm

density was significantly ($p < 0.05$) higher in rabbits exposed to the highest concentration of clove powder than in animals fed a diet containing 1% Madagascar cardamom. Furthermore, the sperm density values recorded in rabbits after two months of treatment were significantly ($p < 0.05$) higher in animals from the control group and in those fed diets containing 0.5% Madagascar cardamom and 0.5% and 1% clove, compared to the values for the same characteristic after one month of treatment.

Sperm motility, the percentage of motile and rapidly progressing sperm after 1 month of treatment, the proportion of immobile spermatozoa, and the percentage of spermatozoa moving in a straight line after 2 months of treatment-all recorded in animals fed diets containing additives, regardless of type and concentration-increased; however, this increase was significant ($p < 0.05$) only with 1% clove compared to the control group.

Conversely, the addition of powdered additives, regardless of their concentration in the rabbits' diet, resulted in a decrease in the percentage of immotile spermatozoa; however, this reduction was significant ($p < 0.05$) only in animals fed diets containing 0.5 and 1% Madagascar cardamom and 1% cloves compared to the control group at one-month treatment. Characteristics such as local motility and straight-line speed of sperm were not significantly affected ($p > 0.05$) by the additives, regardless of type and concentration, compared to the values of these characteristics recorded in the control group.

Table 4. Effect of Madagascar cardamom seed powder and clove powder on sperm density and motility.

Semen characteristic	Treatment duration (months)	Treatments					p-value
		T0	T1	T2	T3	T4	
Density (10^6/mL)	1	128.68 ± 17.94^{cB}	221.40 ± 20.10^{bB}	277.64 ± 36.88^{a}	207.94 ± 18.94^{bB}	193.69 ± 3.23^{bB}	0.01
	2	328.54 ± 12.25^{abA}	373.49 ± 46.88^{abA}	293.81 ± 51.04^{b}	352.30 ± 39.56^{abA}	409.06 ± 60.53^{aA}	0.05
Motile spz (%)	1	49.73 ± 3.87^{c}	70.65 ± 11.06^{a}	65.04 ± 2.10^{ab}	59.36 ± 6.69^{bc}	69.81 ± 1.13^{aB}	0.02
	2	70.97 ± 12.02	70.29 ± 6.08	76.25 ± 11.15	68.76 ± 3.10	77.34 ± 3.81^{A}	0.60
Rapidly motile spz (%)	1	1.50 ± 0.10^{bB}	0.79 ± 0.51^{cB}	0.89 ± 0.16^{cB}	0.32 ± 0.03^{dB}	2.15 ± 0.09^{a}	0.01
	2	1.90 ± 0.04^{A}	1.81 ± 0.52^{A}	2.21 ± 0.32^{A}	1.95 ± 0.62^{A}	1.97 ± 0.75	0.85
Locally motile spz (%)	1	50.45 ± 10.74	54.97 ± 9.17	56.62 ± 6.71	49.04 ± 8.52	54.42 ± 3.65	0.68
	2	57.85 ± 7.02	59.79 ± 8.65	60.05 ± 3.53	60.01 ± 5.58	59.64 ± 9.26	0.99
Non-motile spz (%)	1	50.27 ± 12.46^{a}	29.35 ± 13.14^{b}	34.96 ± 5.50^{b}	40.64 ± 7.50^{abB}	30.19 ± 2.36^{b}	0.01
	2	29.03 ± 4.87^{ab}	29.71 ± 2.17^{ab}	23.75 ± 8.13^{b}	31.24 ± 1.16^{aA}	22.66 ± 9.34^{ab}	0.20
Straight-line speed of spz	1	3.11 ± 0.20	3.79 ± 0.59	3.78 ± 1.32	2.92 ± 0.36	4.02 ± 0.66	0.33
	2	3.75 ± 0.83	3.47 ± 0.19	4.20 ± 1.75	3.07 ± 0.21	3.58 ± 0.90	0.69
Spz moving in a straight line (%)	1	12.43 ± 1.64^{bB}	12.85 ± 1.37^{bB}	15.65 ± 0.97^{aB}	4.97 ± 0.88^{cB}	15.00 ± 1.58^{a}	0.01
	2	16.42 ± 1.21^{bA}	16.43 ± 2.03^{bA}	20.90 ± 0.88^{aA}	15.36 ± 0.56^{bA}	15.71 ± 3.74^{b}	0.01

T0: control treatment; T1: 0.5% Madagascar cardamom; T2: 1% Madagascar cardamom; T3: 0.5% cloves; T4: 1% cloves; ^{a,b}: Means denoted by different letters for the same trait within the same row are significantly different ($p < 0.05$); ^{A,B}: Means denoted by different letters within the same column for the same trait are significantly different ($p < 0.05$); Spz: spermatozoa.

Considering the treatment duration, the percentages of rapidly progressing sperm and sperm moving in a straight line, recorded after two months of treatment, increased significantly ($p < 0.05$) compared to the values recorded after one month of treatment, in both the control and the test groups.

3.5. Effect of Madagascar Cardamom Seed Powder and Clove Powder on Sperm Viability, Morphology, and Membrane Integrity

Table 5 summarizes the effect of Madagascar cardamom seed powder and clove powder, as well as treatment duration, on sperm viability, morphology, and membrane integrity. The results show that the addition of clove powder at concentrations of 0.5% and 1% resulted in a comparable rate of intact membranes, but one that was significantly ($p < 0.05$) higher compared to animals in the control group and animals fed diets containing 0.5% and 1% Madagascar cardamom after one month of treatment. Furthermore, the use of the various additives in the rabbits' feed, regardless of concentration and duration of treatment, did not significantly affect ($p > 0.05$) the percentage of live spermatozoa or the percentage of normal spermatozoa compared to the control group.

Table 5. Effect of Madagascar cardamom seed powder and clove powder on sperm viability, morphology, and membrane integrity.

Semen Characteristics	Treatment duration (months)	Treatments					p-value
		T0	T1	T2	T3	T4	
Live spz (%)	1	80.50 ± 7.93	76.37 ± 8.73	75.37 ± 16.96	75.75 ± 11.87	90.67 ± 6.25	0.41
	2	97.50 ± 1.50	98.12 ± 1.18	96.12 ± 5.76	97.17 ± 2.08	98.00 ± 1.50	0.91
Intact membranes (%)	1	94.75 ± 3.68^{b}	95.50 ± 0.40^{b}	94.00 ± 1.15^{b}	99.00 ± 1.15^{a}	99.33 ± 1.15^{a}	0.01
	2	99.17 ± 1.04	98.50 ± 1.08	99.25 ± 0.96	99.17 ± 1.04	100.00 ± 0.00	0.40
Normal spz (%)	1	74.25 ± 48.84	95.25 ± 4.19	97.00 ± 1.82	93.50 ± 3.70	98.83 ± 0.76	0.58
	2	98.00 ± 0.87	98.87 ± 0.63	98.75 ± 0.64	98.33 ± 1.53	98.67 ± 0.58	0.71

T0: control treatment; T1: 0.5% Madagascar cardamom; T2: 1% Madagascar cardamom; T3: 0.5% cloves; T4: 1% cloves; ^{a,b}: means denoted by different letters within a row for the same characteristic are significantly different ($p < 0.05$). Spz: spermatozoa.

4. Discussion

Reproduction is essential because it ensures the continuity and survival of the species. To ensure this survival, seed quality is a critical factor, as it plays a vital role in reproduction. This study was conducted to evaluate the effect of incorporating powders of Madagascar cardamom (*Aframomum angustifolium*) and cloves (*Syzygium aromaticum*) into the diet on the sperm characteristics of local rabbits. The results show that, after one month of treatment, the semen volume of rabbits fed a diet containing 0.5% or 1% cloves was higher than that of the control group. This suggests an early stimulatory effect of bioactive compounds, such as eugenol and phenols, present in this plant, on seminal plasma production. However, this

effect may diminish over time, either due to physiological adaptation of the organism or because the initial stimulation reaches a plateau. This conclusion is consistent with the studies by [12], who showed that incorporating *Lippia citriodora* at a concentration of 0.1% into the diet of male rabbits had negative effects on semen volume. After two months, the treatment containing 0.5% Madagascar cardamom showed a higher sperm volume, which is consistent with the studies by [13], which demonstrated that sperm volume increased significantly in rabbits receiving aqueous thyme extract at a dose of 50 mg/kg, compared to the control group. The high dose of Madagascar cardamom (1%) did not provide any additional benefit and may even have reduced the expected effect. However, the other treatments yielded comparable results. This finding could be explained by an optimal effect of the low dose of Madagascar cardamom, combined with the body' s gradual adaptation to prolonged treatment, as well as differences in the mechanism of action between the two plants. It should also be noted that variations in semen volume can be caused by genetic differences, the reproductive and health status of the males, their age, the frequency of collections, the season, and management practices [14]. The pH measured after two months of treatment suggests that incorporating 0.5% Madagascar cardamom into the feed, as well as adding cloves at any concentration, induced a slightly alkaline seminal pH. The pH of the semen ranged from 6.7 at the first collection to 7.55 at the second. These values are considered normal and comparable to those reported by [15]. Data from the literature reveal variability in semen pH among the different strains and breeds studied (ranging from 6.94 to 7.63) [16]-[18]. These results are also consistent with those of [19], who reported a non-significant difference in semen pH between animals fed a diet containing thyme essential oil and the control group. With regard to color, the treatments using Madagascar cardamom and cloves did not significantly alter the color of the semen. The majority of the samples tested were milky white in color, regardless of the treatment or the time period of the trial. These results indicate good semen quality. According to [11], a milky white color indicates good sperm viability. Changes in color (yellowish, pinkish, or transparent) are often a sign of low concentration, infection, or stress. The variations observed fall within the normal physiological color range for rabbit semen, suggesting that these additives do not alter the visual quality of the ejaculate and allow for the maintenance of normal sperm production. This study revealed an increase in sperm motility in rabbits treated with 1% clove, regardless of the treatment period. This result may be linked to the antioxidant properties of clove, which protect sperm membranes from oxidative damage and preserve and improve sperm motility and vitality. Phenolic compounds reduce oxidative stress and thereby preserve sperm motility. Thus, clove supplementation, particularly at 1%, promoted better functional sperm quality in rabbits, resulting in increased sperm viability. This result is consistent with the studies by [20], which support the hypothesis that sperm motility is linked to viability, which is one of the indicators of sperm quality. Overall, sperm density and kinetic parameters indicate that plant-

based additives have a beneficial effect on male reproductive function, likely through enhanced protection of testicular tissue against oxidative stress-a mechanism already well documented in andrology [21] [22]. Animals treated with 1% Madagascar cardamom exhibited higher sperm density after one month of treatment. A higher concentration of Madagascar cardamom could therefore stimulate early spermatogenesis or improve sperm release into the ejaculate. This trend is consistent with studies showing that the bioactive compounds of *Aframomum melegueta* exert beneficial effects on male reproductive function in experimental models, particularly in cases of endocrine imbalance or metabolic stress [23] [24]. After two months, the animals that received 1% clove extract had the highest density. After two months, the animals that received 1% clove oil had the highest sperm density. This result can be explained by the high content of eugenol and other phenolic compounds with strong antioxidant activity in clove oil. In a study on male rabbits, the addition of clove oil improved sperm physical properties, testosterone levels, and several physiological indicators, suggesting that this spice may act as a useful reproductive phytogen when used at an appropriate dose [9]. Regarding the proportion of motile spermatozoa, this increased overall after two months in all groups, while the proportion of immotile spermatozoa decreased, with a significant reduction already visible after one month in animals treated with 1% Madagascar cardamom and clove. This pattern is biologically consistent: motility is highly sensitive to plasma membrane integrity, mitochondrial function, and redox balance. An excess of ROS disrupts membrane fluidity, impairs oxidative phosphorylation, and reduces the efficiency of flagellar movement; conversely, adding substances with antioxidant properties to the animals' diet can restore these functions [21] [22].

5. Conclusion

Dietary supplementation with 1% cloves, and, to a lesser extent, 0.5% Madagascar cardamom, appears to be a promising phytogenic strategy for improving sperm quality and, potentially, the reproductive performance of male rabbits. These results open up interesting prospects for the use of these natural additives in rabbit farming as an alternative to synthetic reproductive stimulants. However, further studies, particularly those focusing on the hormonal mechanisms involved, the optimal duration of supplementation, and the effects on actual fertility (pregnancy rates, litter size), would be necessary to confirm and further investigate these observations.

Statement of Ethical Approval

The experimental protocols used in this study were approved by the Ethics Committee of the Department of Animal Science at the University of Dschang (EC-DAS-UDs 23/02/2022/UDs/FASA/DSAES). The protocols were in conformity with internationally accepted ethical guidelines for the use and care of laboratory animals, as described in the European Community guidelines.

Author Contributions

Conceptualization, Tchoffo Herve and Ousmane Issa Abdel Djalil; methodology, Dobgima Alex Boris; software, Tchoffo Herve; validation, Tchoffo Herve and Ousmane Issa Abdel Djalil; formal analysis, Tchoffo Herve; investigation, Dobgima Alex Boris; data curation, Tchoffo Herve; writing—original draft preparation, Ousmane Issa Abdel Djalil; involved in conducting the study and collecting the data, Tchouala Tsogang Thierry; owner of the farm and the animals, Djonko Dongmo Charles; writing—review and editing, Ngoula Ferdinand; visualization, Ngoula Ferdinand; supervision, Tchoffo Herve. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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