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Studies of the effects of aqueous extract of *Garcinia kola* on fatigue and memory in Wistar Rats

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Abstract

The objective of this study is to evaluate the possible effects of the aqueous extract of *Garcinia kola* at the dose of 1000 mg/kg (EAGk) on the decrease of vigilance. This decrease in alertness is due to fatigue and memory impairment promoted by sleep deprivation for 7 consecutive days on wistar rats. 18 male rats aged 8 weeks weighing between 200 and 220g, divided into 3 groups of 6 rats, were subjected to sleep deprivation using a modified multiple platform. On the seventh day, the groups were subjected to different behavioral tests. It appears from our results that: In terms of fatigue, the analysis of the results of the openfield and the elevated cross labyrinth indicates that the rats treated with aqueous extract of *Garcinia kola*, present reduction of anxiety. The exhaustive nation test shows that the rats treated with aqueous extract of *Garcinia kola* have a good muscular performance. Regarding memory disorders, these rats treated with aqueous extract of Garcinia kola and deprived of sleep do not show any sign of memory impairment in the Y- labyrinth and objects recognition tests. In general, our results showed that the aqueous extract of *Garcinia kola* prevents the decrease in vigilance through its anxiolytic effects that eliminate anxiety and improves muscle performance but especially that allow increasing the learning capacity and the potential of memorization.

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Introduction

In humans and vertebrates in general, sleep can be defined as a periodic state of tranquillity in which sensory information processing is minimal and no interaction with congener or the environment exists (Borbely, 2000). In a broad sense, sleep is defined as a period of inactivity. Sleep is divided into several phases: pre-sleep or sleep - inducing, light, medium and deep sleep, and finally REM (Rapid Eye Movement) sleep. The first phases of sleep serve to eliminate physical fatigue while REM sleep eliminates mental fatigue. Loss of sleep, even of only a portion of sleep, leads to significant changes in the electrophysiological activity of the brain (Borbely, 2000 and Dijk *et al.*, 1987). Among the main neurobiological modifications found, the first symptoms of sleep deprivation concern "high-level" brain functions such as mood, central fatigue (Dalsgaard and Secher, 2007) and cognitive functions (Maquet, 2001; Banks and Dinges, 2007) such as recognition disorders (Alzoubi *et al.*, 2013) and negative emotions (Pires *et al.*, 2013). Yet, recent surveys show that 80% of rural populations in developing countries and 85% of sub-saharan population use medicinal plants as their main treatment and the majority of therapies involve the exploitation of the active principle of medicinal plants (WHO, 2002; Biyiti *et al.*, 2004; Dibong *et al.*, 2011a, c; Mpondo and Dibong, 2012). In Côte d'Ivoire, according to WHO/UNICEF (2005), traditional medicine is experiencing unprecedented growth and is the mainstay of primary health care for the majority of the population thanks to its geographical, economic and cultural accessibility. Nearly 1,500 species of medicinal plants have been identified Adjanohoun and Aké-Assi (1979), Aké-Assi (1984), Tra Bi (1997), N'Guessan (2008) etc. These plants are used to treat various pathologies (malaria, hemorrhoids, rheumatism, dermatosis, febrile affection, sexual impotence, etc.). One of its medicinal plants species much used, is Garcinia kola. Through its compounds, Garcinia kola seeds prevent or relieve colic disorders or cure headaches or chest pain, suppress colds, coughs and are often used in the treatment of cirrhosis and hepatitis (Ogu and Agu, 1995). They have a blood pressure regulating effect and relieve abdominal and ulcer pain (Alaje *et al.*, 2014). They are chewed and used as a stimulant or aphrodisiac (Vivien and Faure, 1996). In these circumstances, it seemed important to us to initiate a study of the effects of the aqueous extract of Garcinia kola in traditional treatments against fatigue and memory disorders induced by sleep deprivation in the wistar rat.

Materials and methods

Materials

Plant material

The plant material consists of seeds of Garcinia kola, bought on the market of Sikensi (Elibou), a city located at 79.8 km from the economic capital of Côte d'Ivoire it was identified by the laboratory of Botany of the UFR Biosciences of the University Félix Houphouët BOIGNY of Cocody from a herbarium of the National Center of Floristics where a specimen has been set down.

Animal material

The study involved white rats, of Wistar strain, 8 weeks old and weighing between 200g and 220g. They were raised in the animal house of the UFR Biosciences of the University Félix Houphouët BOIGNY of Cocody (vivarium). The animals receive food and water ad libitum.

Technical equipment

- Multiple platform reservoirs
- Square-shaped box (58 x 58 x 33cm), with the floor divided into 25 tiles
- Elevated cross labyrinth
- Reservoir for the exhaustive swimming test
- Y- labyrinth

Methods

Sleep deprivation methods

The sleep deprivation method was as described by Medeiros *et al.* (1998). Rats were divided into 3 groups of 6 male Wistar rats aged 8 weeks weighing between 200 and 220g. Sleep deprivation was performed on 2 groups of rats. Sleep deprivation of these 2 groups of rats was possible through the use of the multiple platform modified by Weiyue Zhang *et al.* (2018). This involved placing rats in a 110 × 60 ×

40cm3 lidless opaque plastic water reservoir containing 14 circular platforms of 6.5cm diameter with water up to 1cm from their top surface. Thus, the rats could move inside the reservoir by jumping from one platform to another. When they reached the sleep phase, muscle atony set in, and they fell into the water and woke up. Rats were fed with pellet chow diet and water ad libitum. The process begins at 6:00 p.m. and ends at 8:00 a.m. the next day, for a total of 14 hours per day, for 7 days. The water in the tank is changed daily during these 7 days.

Behavioral evaluation of the effects of EAGk on fatigue

Open Field Test

This test was adapted from the study described by Hall (1934) in rats. The test is based on the natural tendency of rodents to explore an unfamiliar space, which allows us to measure their locomotor and exploratory activities. The device is square (70 x 70 x 40cm) and the floor has been divided into 25 tiles. The experimenter is located one meter away from the open field. He makes his observations from the computer connected to a camera placed at a height that allows him to visualize inside the device. The animals (n = 5) were placed in the center of this device. Observations were made on locomotors capacity (number of squares crossed) and vertical exploration (how often the animal stood up on its hind legs, leaning or not on the wall) Almagro (1976).

Elevated Cross labyrinth Test

This test was previously described by Pellow *et al.* (1986) in rats. The test is based on the preference of rats to be in confined and dark places, which are more reassuring for the animal, which allows to assess the anxiety-like behavior in the animal. Thus, an animal that explores more in the open arms will be described as "low anxiety" and an animal that remains confined in the closed arms of the device will be described as "anxious". This test is notably used to evaluate the effectiveness of anxiolytic molecules in rodents, resulting in an increase in the time spent exploring in open arms. The device is shaped like a cross and raised to a height of 50cm from the ground. It consists of two open arms (50 × 10cm) without walls, and two other arms closed by walls (50 ×10 × 45cm) that intersect, forming a central platform (10×10cm). The rat is placed on this platform, facing an open arm, and freely explores the apparatus for 5 minutes. The numbers of entries in the open and closed arms as well as the percentage of time spent in the open arms are measured manually. The device is cleaned with 70% ethanol and dried after each rat to limit olfactory traces.

Exhaustive swimming test

The exhaustive swimming test with weight loading was performed as described with minor modifications (Weiyue Zhang *et al.*, 2018). On the last day of the sleep deprivation process, each experimental groups was subjected to the exhaustive swimming test with constant loads (set at the base of the tail) corresponding to 10% of their body weight. The exhaustive swimming test was performed in a swimming reservoir (70 × 30 × 110cm3) with 80cm of warm water (25 ± 3°C) for 1 hour. The rats were then removed from the pool, dried with a paper towel, and returned to their original cages. The pool water was replaced after each session. Exhaustion was determined by observing the loss of coordinated movements and the inability to swim. During the tests, the time of immobility and the number of dives were observed (Detke *et al.*, 1995). A rat is considered immobile when it moves enough to keep its head above water Borsini and Meli (1988).

Behavioral evaluation of the effects of EAGk on memory

Place recognition test in a Y- labyrinth

The protocol used was previously described in rats (Dellu *et al.*, 1992). It is based on the animal's natural tendency to explore its environment. The spatial recognition of the animal reflects an episodic type of memory, since the animal must remember visited arms during the "what and where" acquisition session depending on the "when" delay used. Thus, the place recognition test allows to evaluate the different components of the episodic memory "what, where and when" in a combined way.

The device is a black cardboard box labyrinth in the shape of Y with three arms, marked A (starting arm),

B (familiar arm) and C (new arm) (50 x 16 x 32cm). The behavioral test is performed in two sessions, one of acquisition, the other of reminder, separated by a retention time chosen during the acquisition session, one of the 3 arms of the labyrinth is kept closed "new arm". The animal is then placed in the arm of the Y-shaped labyrinth closest to the experimenter "starting arm", facing the wall, and freely explores the two accessible arms of the labyrinth (starting arm and familiar arm) during 5 min.

After a retention time of one hour, during the reminder session, the 3 arms of the labyrinth are opened and the animal explores them freely for 2 min. The experimenter then measures the time spent in each arm. An animal that remembers the starting and familiar arms will then spend more time exploring the new arm. The familiar arm is randomized between animals so as not to introduce bias related to a possible spatial preference. The device is cleaned with 70% ethanol and then dried after each rat's passage to limit olfactory traces.

Object recognition test (ORT)

The Object Recognition Test (ORT) is a relatively quick and efficient way to test different phases of learning and memory in rodents (Antunes and Biala, 2012). It was originally described by Ennaceur and Delacour (1988) and used primarily in rats; however, since then it has been successfully adapted for use in mice (Lueptow, 2017).

This test assesses the rat's ability to recognize a new object relative to a familiar object in a known environment. After a habituation phase rats are placed in a box (40×40cm) with two identical unbreakable objects (D: 10cm, H: 15cm). The rats are left to explore freely for 10 min and the time spent exploring each object is recorded by video, while the test session consists in replacing a previously explored object by a new one. Rodents have an innate preference for new object; a rodent that remembers the familiar object will spend more time exploring the new object. An animal that does not have memory problems will spend its exploration time on the new object. Rats given a substance with an amnesia effect will have a cognitive deficit during training and a memory lapse. During the test phase, the animal will explore the familiar object as much as the new object, suggesting that it has "forgotten" its training phase (Sanderson *et al.*, 2011).

The test is based on four sessions: a habituation session, a training session, a short-term memory (STM) session and a long-term memory (LTM) session. During the habituation phase, the rat is removed from its cage and placed in the middle of the empty area, allowing it to explore the area for 5 min, then the rat is removed and placed in a holding cage. During the training phase, two identical objects (a; a) are placed in opposite quadrants of the area, the animal explores it for 10 min. During the short-term memory phase, 2 hours after the training phase, the rat is removed from its holding cage and placed in the center of the area where identical objects (a; a) are placed in opposite corners, the animal is allowed to explore freely for 10 min. During the long-term memory phase, a familiar and a new object (a; b) are placed in opposite quadrants of the area and exploration is performed for 10 min for each rat (Lueptow, 2017). The variables measured during short-term memory and long-term memories are:

-Total exploration frequency for both objects for each session.

FF: frequency of exploration of the familiar object.

FN: frequency of exploration of the new object.

- The exploration index (EI) corresponds to the total frequency of exploration of the objects.

EI= FN + FF

- The recognition index (RI) corresponds to the proportion of frequency of visit of the new object by the animal; it thus varies between 0 and 100%.

RI= [FN/ (FN + FF)] x100

Statistical analysis

All statistical analyses were made using Graphpad Instat software. The results were expressed as mean ± SEM (Standard Error on the Mean). To analyze the results of the different treatments, we used the ANOVA (Analysis of Variance) test and the Student-Newman-Keuls test to compare the means of the controls and the treatments.

Result and discussion

Result

Effects of EAGk on fatigue

Effect of EAGk on the level of motor and exploratory activity by the open field test

During five minutes (Fig. 1A), the average of total number of crossed tiles by control A rats was significant (59.67±15.40). When the result of control A rats is compared with the results of control B rats, there is a decrease in the total number of crossed tiles (27.83±6.40) or 53.36%. This decrease is highly significant (Dunnett's: $p < 0.0001$). In the group of rats that received EAGk, there was a 26.82% decrease in the total number of crossed tiles (43.67±5.99), thus not highly significant (Dunnett's: $p < 0.05$). Similarly, in Fig. 1B we have a highly significant (Dunnett's: $p < 0.0001$) decrease in vertical exploration (65.02%) between the group of control B rats (7.17±1.33) and the group of control A rats (20.50±3.39) on one hand. On the other hand, there was a marginally significant (Dunnett's: $p < 0.05$) decrease in vertical exploration of the rats that received EAGk (17.17±1.72) compared to the control A rats grou (20.50±3.39). This decrease was about 16.24%.

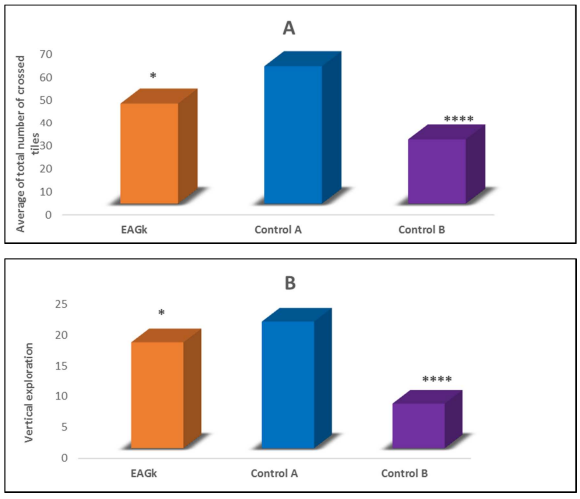

Fig. 1. Effect of aqueous extract of *Garcinia kola* on motor activity and vertical exploration of rats in an open field test.

Cognitive effect of EAGk on anxiety level by the test of elevated cross labyrinth

The results obtained by placing the animals in the elevated cross labyrinth show that EAGk-treated rats and control B rats differently explore this unfamiliar environment differently compared to control A rats. In Fig. 2A, we see that the number of open-arm entries (22.19%) decreased significantly (Dunnett's: $p < 0.01$) for control B rats (8.17±0.75) compared to control A rats (10.50±0.84). For EAGk-treated rats (11.33±1.03), there was a non-significant increase (7.90%) (Dunnett's: $p = 0.33$) compared with control A rats (10.50±0.84). The time spent by rats in open arms (77.66%) is also highly significantly (Dunnett's: $p < 0.0001$) reduced in control B rats compared to the control A rats group (15.67±1.75 Vs 3.50±1.05). Then, when comparing the EAGk-treated rats to the control A rats, the time spent in the open arms by the EAGk-treated rats (18.67±2.16 Vs 15.67±1.75) has a marginally significant ($p < 0.05$) increase of about 19.14% (Fig. 2B). On the other hand, in Fig. 2C, the comparison of control B rats to control A rats (16.17±1.17Vs 12.00±0.89), shows a highly significant (Dunnett's: $p < 0.0001$) increase in the number of entries into the closed arms. And when the EAGk-treated rats (14.00±0.89Vs 12.00±0.89), there was a marginally significant (Dunnett's: $p < 0.05$) increase in the number of entries into the closed arms. These increases are in the order of 34.75% and 16.66%, respectively. Regarding the time spent in the closed arms (Fig. 2D), there was a highly significant (Dunnett's: $p < 0.0001$) increase in time of control B rats (199.8±11.48s) compared to the time spent in the closed arms of control A rats (113.3±4.63s). On the other hand, the time spent in the closed arms by EAGk-treated rats (98.67±3.67) was significantly reduced (Dunnett's: $p < 0.01$) compared with the time spent in the closed arms by control A rats (113.3±4.63s).

Effect of EAGk on level of muscle performance by exhaustive swimming test

The result of the exhaustive swimming test (Fig. 3) shows that the control B rats (51.00±10.32s) have a highly significant (Dunnett's: $p < 0.0001$) decrease in swimming time than that of the control A rats (1800±0.0s), which is 97.16% of swimming time reduction. Also, the group of EAGk-treated rats showed a highly significant (Dunnett's: $p < 0.0001$) decrease in swimming time compared to A control rats (1365±71.57 Vs 1800±0.0s). This decrease is of the order of 24.16%.

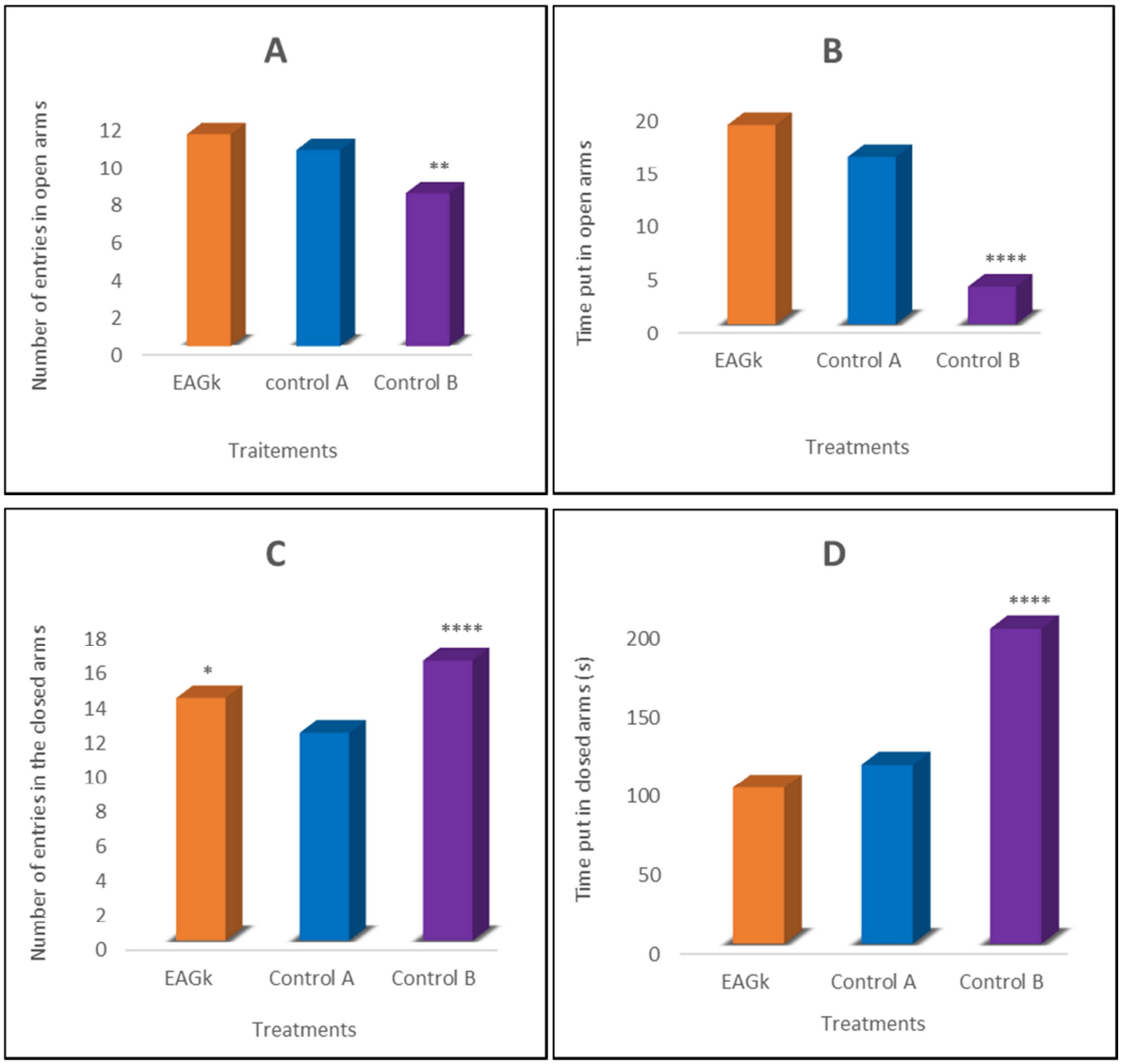

Fig. 2. Effect of EAGk on rat anxiety in an elevated cross labyrinth test.

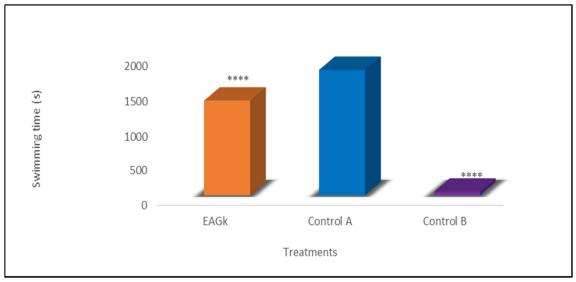

Fig. 3. Effect of EAGk on rat swimming time in a momory swimming test.

Effects of EAGk on memory

Effects of EAGk on spatial working memory capacity

The study of the effects of *Garcinia kola* consumption on spatial working memory, in this Y- labyrinth test, on rats deprived of REM sleep for 7 days, is represented by the percentage of alternation in Fig. 4. Indeed, when comparing the levels of percentage of alternation between the different groups of rats, we observe a significant decrease ($p<0.05$) in the number of alternations of the group of rats deprived of REM sleep for 7 days compared to the control group that were not deprived of REM sleep. On the other hand we have a non-significant decrease ($p>0.05$) between the group of rats deprived of REM sleep but given the aqueous extract of *Garcinia kola* for 7 days and the control group that were not deprived of REM sleep. When comparing the number of alternations of the group of rats deprived of REM sleep but given the aqueous extract of *Garcinia kola* for 7 days to the group of rats deprived of REM sleep for 7 days and not given the aqueous extract of *Garcinia kola*, there was a significant increase ($p<0.05$). These results

show that EAGk, improves working memory following sleep deprivation for 7 days.

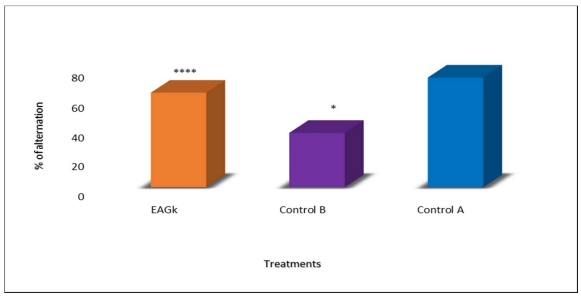

Fig. 4. Effect of EAGk on rat spatial working memory capacity in a Y-labyrinth test.

Effects of EAGk on recognition memory capacity in an object recognition test

Effects of EAGk on recognition short-term memory (STM)

The results in Fig. 5 show a difference in object recognition index between non-sleep deprived control rats and sleep deprived rats for 7 days, treated or not. Indeed, the object recognition indexes of the rats that were not deprived of sleep and those deprived of sleep but treated with Garcinia kola have a percentage higher than 50% or respectively 70.05% and 74.40%. On the other hand, the group of rats deprived of sleep and which did not receive any treatment, presents a percentage of object recognition index of 34.82%. Thus, the value of the percentage of the short-term recognition index is not statistically significant between the sleep deprived rats treated with Garcinia kola and the non-sleep deprived control rats. In addition, those of the sleep deprived and untreated rats, have a significantly ($p< 0.001$) lower percentage of the short-term recognition index than the non-sleep deprived control rats.

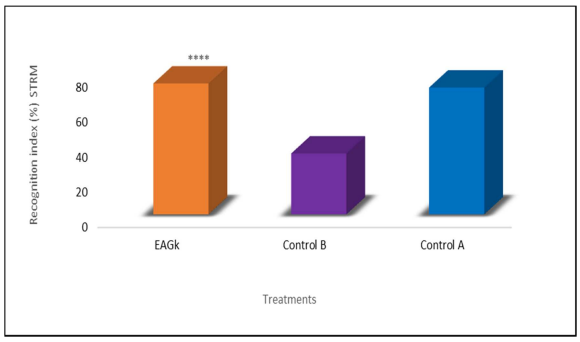

Fig. 5. Effect of EAGk on the short-term recognition memory capacity of rats in an object recognition test.

Cognitive effects of EAGK on long-term recognition memory (LTM)

The analysis of the long-term recognition indixes shows that after 24 hours, the recognition index of the non-sleep deprived rats (68.06%) and those deprived of sleep but treated with *Garcinia kola* (71.49%) is not significant. On the other hand, the sleep deprived and untreated rats have a percentage of object recognition index of 33.80%, therefore, this long-term recognition index is significantly lower ($p< 0.001$) than that of the non-sleep deprived control rats (Fig. 6).

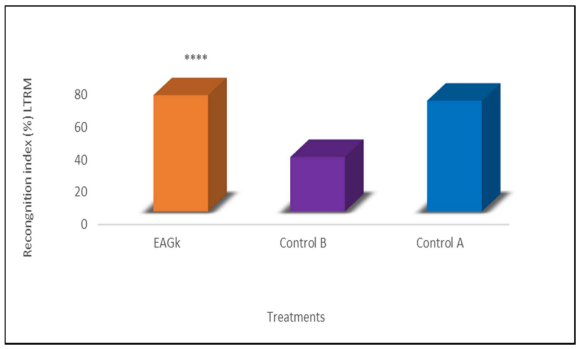

Fig. 6. Effect of EAGk on the long-term recognition memory capacity of rats in an object recognition test.

Discussion

In this study, we were interested in the effect of EAGk consumption on fatigue and memory disorder. It is made possible from a several behavioral test performed on wistar rats.

Regarding fatigue, analysis of the open field results indicated that after sleep deprivation of 14 hours per day for 7 consecutive days, locomotor and exploratory activity in control B rats decreased significantly. Rats that received EAGk treatment had a little decrease in locomotors and exploratory activity. These results showed a decrease in psychomotor activity in sleep-deprived rats. However, in the treated rats with EAGk, there was an improvement in the performance of locomotors and exploratory activity. Therefore, we can say that EAGk is an effective against fatigue. These results were in agreement with the data of Weiyue Zhang *et al.* (2018) in the study on "A central fatigue model for rats using a modified multi-platform method" which show that rodents have the instinct of thigmotaxis, that is to say, once they are

put in the open field, they tend to move quickly to leave the new environment. But at the same time, they are curious about that environment and are eager to explore it by prancing vertically and making horizontal movements. So this decrease in activity in sleep-deprived rats demonstrated an anxious emotion. Indeed, sleep deprivation and the desire to explore a new environment generates an anxiety emotion as evidenced by Ahn (2013). According to him, the conflict between two motivations reflects the anxious mood. But, for those who received the EAGk, this state of anxiety is hardly noticed. The same data was obtained with the study of black cumin seed oil in rats.

According to Perveen *et al.* (2014), the treatment with black cumin significantly increases the number of central tiles run by the rats in the open field test and therefore black cumin has an effect on anxiety. Moreover, the results of the elevated cross labyrinth indicated a high level of anxiety in the group of B control rats and virtually no anxiety in the group of rats receiving EAGk treatment. This is reflected in a decrease in the time spent in the open arms of the control B group of rats when compared to the control A group, and no observable change between the group of rats receiving EAGk treatment and the control A batch of rats. Thus, all these results suggest that EAGk behaves like an anxiolytic. Indeed, the increase in the number of entries and the time spent in the open arms are considered to be the most representative indexes of anxiolytic activity (Pellow *et al.*, 1986). In this device, rats normally prefer to spend much of their time in the closed arms. This behavior appears to reflect an aversion to open arms that is generated by fear of open spaces. Drugs that increase exploration of open arms are considered anxiolytic and the reverse is true for anxiogens (NicDhonnchadha *et al.*, 2003).

The open field test and the elevated cross labyrinth test have shown that sleep deprivation is associated with altered locomotor activity and elevated anxiety in the animal. However, when the animal was subjected to EAGk treatment over a period of time, the alteration in locomotors activity and anxiety did not set in. The same observation is made at the level of muscular performance. Indeed, the action of EAGk on sleep-deprived rats is observed during the exhaustive swimming test. In this test, the swimming time of the A control rats was longer than that of the rats receiving EAGk treatment. It was longer compared to that of control B rats. These results showed that sleep deprivation induces poor muscle performance due to fatigue, but under the effect of EAGk, there was a resistance to muscle fatigue. These obtained results, are identical to the results of Rahman *et al*, 2017 in the study of Nigella sativa seed extract. This author was able to demonstrate that the hydroalcoholic extract of Nigella sativa relieve physical fatigue. The effect of these extracts on fatigue due to their constituents. Indeed, many investigations have highlighted the richness of Nigella oil in thymoquinone (TQ), polyphenols (Cheikh-Rouhou *et al.*, 2007 and Cheikh-Rouhou *et al.*, 2008), flavonoids (Merfort, 1997), folic acid, vitamin E, potassium, calcium, iron, sodium and selenium (Al-saleh *et al.*, 2006). The similarity of these compounds could justify the actions of EAGk on fatigue, namely the elimination of anxiety and the improvement of muscular performance.

Behavioral tests of the open field and elevated cross labyrinth have shown that EAGk has an effect on fatigue. However, when this fatigue persists, it leads to muscle pain and memory impairment (Finsterer, 2012). In this case focusing on memory disorders in the second part of our study seemed important to us.

First, we were interested in spatial working memory capacity through the Y-labyrinth test. In this test, rats deprived of sleep for 7 days showed a significant decrease in percentage of alternation compared to non-sleep deprived rats. While the rats receiving EAGk treatment had a non-significant decrease in percentage of alternation compared to non-sleep deprived rats. These data reflected the fact that rats deprived of sleep for 7 days, were unable to remember the previously visited arm since there is a very low number of alternations, thus reflecting an alteration related to sleep deprivation. However, this was not observed in the treated rats. So, they managed to establish a difference between the arms visited. These

results showed that EAGk prevents the degradation of learning memory and especially memorization.

Indeed, in other researches where we do not have treatment as in the fear conditioning paradigm, sleep deprivation just after learning disrupts spatial memory formation (Smith & Rose, 1996; Smith & Rose, 1997). Also, sleep deprivation before conditioning in human beings permitted to reduce the encoding of temporal (Harrison & Horne, 2000; Yoo *et al.*, 2007), verbal (Drummond & Brown, 2001; Drummond *et al.*, 2000) and emotional (Walker & Stickgold, 2006) memories. These findings made in his research and absent in our study here, effectively show that the EAGk has an action on the capacity of spatial working memory. This action is also observed at the level of recognition memory through short-term memory and long-term memory through the object recognition test (O.R.T.). In this part of our study, sleep deprivation of rats for 7 days resulted in a decrease in the short-term recognition index compared to the short-term recognition index of non-sleep deprived rats and was less than 50 percent. In sleep-deprived rats treated with EAGk, the short-term recognition index decreases relative to the short-term recognition index of non-sleep-deprived rats but is above 50%. We have the same observations with the long-term recognition index. These results showed that for sleep deprived rats, we have a decrease in the object recognition index reflecting neurobehavioral variation such as reduced learning efficiency and memory potential (Gasmi *et al.*, 2017).

Also prevented the formation of new object recognition memory (Palchykova *et al.*, 2006) where the animal learns to associate an environment but not where the animal learns to associate a stimulus, such as a sound (Graves *et al.*, 2003); Vecsey *et al.*, 2009). This is not the case with the treated rats. EAGk appears to show an improvement in memory disorder due to sleep deprivation. This observation is similar to studies by Lu *et al.* (2017) on Rh1 ginsenoside, one of the saponins and chemical constituents of ginseng (Panax ginseng) root. They tested Rh1 in sleep deprivation-induced cognitive disorder and it appears to improve memory in normal mice and mice made amnesic by introducing scopolamine. This similarity of results leads us to consider that chronic consumption of *Garcinia kola* could be considered a solution to memory disorder better than cognitive enhancing drugs (Valeria *et al.*, 2013). Cognitive enhancers, such as modafinil, donepezil, caffeine, and nicotine, which are used to improve cognitive performance, have beneficial effects on cognitive tasks such as attention and working memory in humans, primates, and sleep-deprived rodents.

They are able to prevent sleep deprivation-induced long-term memory disorder in aversive-motivated emotional memory tasks (Minzenberg and Carter, 2008; Piérard *et al.*, 2007). However, these cognitive stimulants have side effects, including addiction, which makes their use difficult. *Garcinia kola* contains saponins (Harborne, 1984) and vitamin E (Kirk and Sawyer, 1998), which gives it the power to reverse sleep deprivation-induced cognitive disorder (Valeria *et al.*, 2013). Thus, like ginsenoside Rh1, *Garcinia kola* has beneficial effects on memory disorder in behavioral tests, particularly in hippocampus-dependent tasks (Wang *et al.*, 2009; Hou *et al.*, 2014, Smith *et al.*, 2014).

In general, our results have shown that the aqueous extract of Garcinia kola has on the one hand, an action on fatigue (physical and central) by eliminating stress and improving muscle performance. On the other hand, the aqueous extract of *Garcinia kola* has an action on memory. It increases the efficiency of learning and the potential of memorization.

Fatigue and memory are two important elements in maintaining vigilance. Vigilance is a physiological state of the organism that receives and responds to stimuli (Koella W.P., 1982). It is a state of awake and attentive consciousness. It is characterized not only by an ability to react appropriately to any stimulation, but also by a capacity to remember events that occur during a given period of time. And so the actions of the aqueous extract of *Garcinia kola*, on fatigue and memory, are made possible by its constituents that give it anxiolytic and energy properties.

Conclusion

All this work has demonstrated that there is an action of the aqueous extract of *Garcinia kola* against the decline in vigilance through fatigue and memory problems. The aqueous extract of *Garcinia kola* acts through its anxiolytic and energetic effects that eliminate stress, improves muscle performance and increases the efficiency of learning capacity and memory potential. These results are consistent with many observations made in humans.

Conflict of interests

The authors have not declared any conflict of interest.

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References

Adjanohoun E, et Aké Assi L. 1979. Contribution au recensement des plantes médicinales de Côte d'Ivoire. Centre National de Floristique, Abidjan: 359 p.

Ahn SH. 2013. Basal anxiety during an open field test is correlated with individual differences in contextually conditioned fear in mice. Animal Cells and Systems **17(3),** 154.

Aké-Assi L. 1984. Flore de Côte d'Ivoire: étude descriptive et biogéographique, avec quelques notes ethnobotaniques. Thèse de Doctorat, Fac. Des Sciences, Université d'Abidjan, 6 fascicules, 1206 p.

Alaje DO, Owolabi KT, Olakunle TP, Oluoti OJ, Adetuberu IA. 2014. Nutritional, Minerals and Phytochemicals composition of Garcinia cola (Bitter cola) and *Aframomum melegueta* (Alligator pepper). Journal of Environmental Science, Toxicology And Food Technology **8(1),** 86-91.

Almagro CB. 1976. Esquemas y practices de farmacologia. Editorial Espaxs, Barcelone (Espagne), 283 pp.

Al-saleh I, Billedo G, El-doush I. 2006. Levels of selenium, DL-α-tocopherol, DL-γ-tocopherol, all-trans-retinol, thymoquinoneand thymol in different brands of *Nigella sativa* seeds. Journal of Food Composition and Analysis **19,** 167-75.

Alzoubi KH, Khabour OF, Tashtoush NH, Al-Azzam SI, Mhaidat NM. 2013. Evaluation of the Effect of Pentoxifylline on Sleep- Deprivation Induced Memory Impairment. Hippocampus **23(9),** 812-819.

Antunes M, Biala G. 2012. The novel object recognition memory: neurobiology, test procedure, and its modifications. Cognitive Processing **13(2),** 93-110.

Banks S, Dinges DF. 2007. Behavioral and physiological consequences of sleep restriction. Journal of Clinical Sleep Medicine **3(5),** 519-528.

Biyiti LF, Meko'o DJL, Tamzc V, Amvam Zollo PH. 2004. Recherche de l'activité antibactérienne de quatre plantes médicinales camerounaises. Pharmacopée et médecine traditionnelle africaine **13,** 11-20.

Borbely AA. 2000. Introduction, chapter The Regulation of sleep. Human Frontier Science Program, Strasbourg (France), pp 17–25.

Borsini F, Meli A. 1988. Is the forcedswimming test a suitable model for revealing antidepressant activity? Psychopharmacology **94,** 147-60.

Cheikh-Rouhou S, Besbes S, Hentati B. 2007. *Nigella sativa* L. Chemical composition and physicochemical characteristics of lipid fraction. Food Chemistry **101,** 673-81

Cheikh-Rouhou S, Besbes S, Lognay G. 2008. Sterol composition of black cumin (*Nigella sativa* L.) and Aleppo pine (*Pinus halpensis* Mill.) seed oils. Journal of Food Composition and Analysis **21,** 162-8.

Dalsgaard MK, Secher NH. 2007. The Brain at Work: A Cerebral Metabolic Manifestation of Central Fatigue. Journal of Neuroscience Research **85(15),** 3334-3339.

Dellu F, Mayo W, Cherkaoui J, Le Moal M, Simon H. 1992. A twotrial memory task with automated recording: study in young and aged rats. Brain Research **588,** 132-139.

Detke MJ, Rickels M, Lucki I. 1995. Active behaviors in the rat FST differentially produced by serotonergic and noradrenergic anti-depressants. Psychopharmacology **119,** 47-54

Dibong SD, MpondoMpondo E, Ngoye A, Kwin NF. 2011c. Plantes médicinales utilisées par les populations bassa de la région de Douala au Cameroun. International Journal of Biological and Chemical Sciences **5,** 1105-1117.

Dibong SD, MpondoMpondo E, Ngoye A, Kwin NF, Betti JL. 2011a. Ethnobotanique et phytomédecine des plantes médicinales vendues sur les marchés de Douala, Cameroun. Journal of Applied Biosciences **37,** 2496-2407.

Dijk DJ, Beersma DG, Daan S, Bloem GM, Van den Hoofdakker RH. 1987. Quantitative analysis of the effects of slow wave sleeps deprivation during the first 3 h of sleep on subsequent eeg power density. European archives of psychiatry and neurological sciences **236(6),** 323-328.

Drummond SP, Brown GG. 2001. The effects of total sleep deprivation on cerebral responses to cognitive performance. Neuropsychopharmacology, official publication of the American College of Neuropsychopharmacology **25,** 68-73

Drummond SP, Brown GG, Gillin JC, Stricker JL, Wong EC, Buxton RB. 2000. Altered brain response to verbal learning following sleep deprivation. Nature **403,** 655-657

Ennaceur A, Delacour J. 1988. A new one-trial test for neurobiological studies of memory in rats. Behavioural Brain Research **31,** 47-59.

Finsterer J. 2012. Biomarkers of peripheral muscle fatigue during exercise. BMC Musculoskelet Disord **13,** 218.

Gasmi S, Rouabhi R, Kebieche M, Boussekine S, Salmi A, Toualbia N, Taib CH, Bouteraa Z, Chenikher H, Henine S, Djabri B. 2017. Effects of Deltamethrin on striatum and hippocampus mitochondrial integrity and the protective role of Quercetin in rats. Environnemontale Science Pollution Reseach **24(19),** 16440-16457

Graves LA, Heller EA, Pack AI, Abel T. 2003. Sleep deprivation selectively impairs memory consolidation for contextual fear conditioning. Learning & memory **10,** 168-176

Hall CS. 1934. Emotional behaviour in the Rat. I. Defecation and urination as mesures of individual differences in emotionality. Journal of Comparative Psychology **18,** 385-403.

Harborne J. 1984. Un guide pour les techniques modernes de l'analyse des végétaux. Harborne J B, éditeur. London: Chapman and Hall; 192 p.

Harrison Y, Horne JA. 2000. The impact of sleep deprivation on decision making: a review. Journal of experimental psychology **6,** 236-249

Hou JG, Xue JJ, Lee M, Yu JJ, Sung C. 2014. Long-term administration of ginsenoside Rh1 enhances learning and memory by promoting cell survival in the mouse hippocampus. International Journal of Molecular Medicine **33,** 234-240.

Kirk RS, Sawyer R. 1998. La composition et l'analyse des aliments de Pearson. Éditeur Longman Education Ltd au Royaume-Uni pp.707-708.

Koella WP. 1982. Amodern neurobiological concept of vigilance. Experientia **38(12),** 1426-37

Lu C, Shi Z, Dong L. 2017. Exploring the effect of ginsenoside Rh1 in a sleep deprivation-induced mouse memory impairment model. Phytotherapy Research **31,** 763-70.

Lueptow LM. 2017. Novel Object Recognition Test for the Investigation of Learning and Memory in Mice. Journal of Visualized Experiments **126,** 55718

Maquet P. 2001. The role of sleep in learning and memory. Science **294 (5544),** 1048-52.

Medeiros R, Lenneberg-Hoshino C, Hoshino K, Tufik S. 1998. Neuroethologic differences in sleep deprivation induced by the single-and multiple-platform methods. Brazilian Journal of Medical and Biological Research **31(5),** 675-680.

Merfort I, Wray V, Barakat H. 1997. Flavonoltriglycosides from seeds of Nigella sativa. Phytochemistry **46,** 359-63

Minzenberg MJ, Carter CS. 2008. Modafinil: A review of neurochemical actions and effects on cognition. Neuropsychopharmacology **33,** 1477-1502

Mpondo Mpondo E, Dibong SD. 2012. Traditional knowledge on medicinal plants use by ethnic communities in Douala, Cameroon. European Journal of Medicinal Plants **2,** 159-176.

N'Guessan K. 2008. Plantes médicinales et pratiques médicinales traditionnelles chez les peuples Abbey et Krobou du Département d'Agboville (Côte d'Ivoire). Thèse de Doctorat d'Etat ès Sciences Naturelles, Spécialité Ethnobotanique, Université de Cocody-Abidjan (Côte d'Ivoire), UFR Biosciences, Laboratoire de Botanique 335 p.

NicDhonnchadha BA, Bourin M, Hascoët M. 2003. Anxiolytic-like effects of 5-HT2 ligands on three mouse models of anxiety. Behavioural Brain Research **140,** 203-214.

Ogu EO, Agu RC. 1995. A composition of some chemical properties of Garcinia Kola and HPS for the assessment of Garcinia Brewing value. Bioresearch Technology **54,** 1-4.

Organisation Mondiale de la Santé (OMS). 2002. Stratégie de l'OMS pour la médecine traditionnelle pour 2002-2005, Genève. 78p.

Palchykova S, Winsky-Sommerer R, Meerlo P, Durr R, Tobler I. 2006. Sleep deprivation impairs object recognition in mice. Neurobiology of Learning and Memory **85,** 263-271

Pellow S, Chopin P, File SE, Briley M. 1986. Validation of open: Closed arm entries in an elevated plus-maze as a measure of anxiety in the rat. Journal of Neuroscience Methods **14,** 149-167.

Perveen T, Haider S, Zuberi N. 2014. Increased 5-HT levels following repeated administration of *Nigella sativa* L. (black seed) oil produce antidepressant effects in rats. Scientia Pharmaceutica **82,** 161-70

Piérard C, Liscia P, Philippin J. 2007. Modafinil restores memory performance and neural activity impaired by sleep deprivation in mice. Pharmacology, Biochemistry and Behavior **88,** 55-63.

Pires GN, Tufik S, Andersen ML. 2013. Grooming analysis algorithm: Use in the relationship between sleep deprivation and anxiety-like behavior. Progress in Neuro-Psychopharmacology and Biological Psychiatry **41,** 6-10.

Rahman Mahbubur, Dong Kwon Yang, Gi-beumBim, Sei-jin Lee, Shang-jin Kim. 2017. Nigella sativa seed extract attenuates the fatigue induced by exhaustive swimming in rats. Biomedical Reports **6,** 468-474.

Sanderson DJ, Sprengel R, Seeburg PH, Bannerman DM. 2011. Deletion of the GluA1 AMPA receptor subunit alters the expression of short-term memory. Learning and Memory **18,** 128-131.

Smith C, Rose GM. 1996. Evidence for a paradoxical sleep window for place learning in the Morris water maze. Physiology & behavior **59,** 93-97

Smith C, Rose GM. 1997. Posttraining paradoxical sleep in rats is increased after spatial learning in the Morris water maze. Behavioral neuroscience **111,** 1197-1204

Smith I, Williamson EM, Putnam SE, Farrimond J, Whalley BJ. 2014. Effects and mechanisms of ginseng and ginsenosides on cognition. Nutrition Reviews **72,** 319-333.

Tra Bi FH. 1997. Utilisation des plantes, par l'homme, dans les forêts classées du Haut-Sassandra et de Scio, en Côte-d'Ivoire, Thèse de Doctorat de 3ème Cycle, Université de Cocody-Abidjan, F.A.S.T, N° d'ordre: 257/97, 212 p.

Valeria C, Paolo FF, Gigliola GZ, Fabien P, Giuseppe B. 2013. Experimental sleep deprivation as a tool to test memory deficits in rodents. Frontiers in Systems Neuroscience **7,** 106-123.

Vecsey CG, Baillie GS, Jaganath D, Havekes R, Daniels A, Wimmer M, Huang T. 2009. Sleep deprivation impairs cAMP signalling in the hippocampus. Nature **461,** 1122-1125

Vivien J, Faure JJ. 1996. Fruitiers sauvages d'Afrique (Espèces du Cameroun). Ministère Française de la Coopération et CTA. 416 p.

Walker MP, Stickgold R. 2006. Sleep, memory, and plasticity. Annual review of psychology **57,** 139-166.

Wang YZ, Chen J, Chu SF. 2009. Improvement of memory in mice and increase of hippocampal excitability in rats by ginsenoside Rg1's metabolites ginsenoside Rh1 and protopanaxatriol. Journal of Pharmaceutical Sciences **109,** 504-510.

Weiyue Zhang, Wei Zhang, NingDai, Chenxia Han, Fengzhi Wu, Xu Wang, LiboTan, Jie Li, Feng Li, Qingjia Ren. 2018. A Rat Model of Central Fatigue Using a Modified Multiple Platform Method. Journal of Visualized Experiments Neuroscience **138,** 2- 10.

Yoo SS, Hu PT, Gujar N, Jolesz FA, Walker MP. 2007. A deficit in the ability to form new human memories without sleep. Nature neuroscience **10,** 385-392