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The Role of Bromelain as a Natural Remedy in Reducing Post-Exercise Muscle Soreness

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Abstract
Bromelain, an enzyme gotten from pineapples has stirred interest for its ability to reduce muscular pains and slow down delayed onset muscles soreness (DOMS) which occurs after working out or while having exercising routines among athletes and physically active individuals. The purpose of this study was to assess the efficacy of bromelain in attenuating exercise induced-pain, modulating C-reactive proteins and IL-6 levels, stiffness and enhancing recovery. The study involves 30 participants grouped into the experimental and control groups. The intensity of pain was measured by using the Visual Analog Scale (VAS) for pain severity at 24 hours, 48 hours, and 72 hours after exercising. High-sensitivity C-reactive protein and IL-6 content of the blood samples were estimated while survey and physical performance tests were used to assess muscle stiffness, strength, and flexibility. The data showed that the differences in the pain intensity between the experimental and the control group were highly significant for all the time intervals: $P < 0.001$ whilst the reduction of CRP and IL-6 in the experimental group compared to the control was significantly different ($p<0.01$) by 72 hours. Additionally, participants in the experimental group responded more quickly to improvements in muscle stiffness, strength and flexibility and general recovery. The experimental outcome corroborates the promise of utilizing bromelain as a potential replacement for synthetic recovery enhancement agents, and a successful means of preventing muscular damage associated with exercise, and enhancing recuperation pathways.

Keywords: Bromelain, Inflammation markers, Muscle soreness, Pain reduction, Post-exercise recovery

INTRODUCTION
Bromelain, extracted from pineapples has attracted interest for its tendency to relaxing DOMS and as a natural remedy for athletes and other physical active individuals. There is an

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increasing demand by athletes for an alternative to the usual pain relief medications, especially with regard to relaxation of muscles soreness during sports and exercising with bromelain proving to be one of the best solutions (Colletti *et al*., 2021). Some researchers tend to state that the results of early investigations of the impact of bromelain are still rather uncertain. For example, bromelain supplements in an RCT study with 45 amateur athletes who took bromelain after a 90 min intense workout showed small but significant improvement in muscles soreness as compared to the control group (O'Connor *et al*., 2022). In addition to the anti-inflammatory effects, bromelain can enhance the digestion of proteins, and therefore restore the muscles by breaking down the excess protein (Bottega *et al*., 2021).

Some of the Non-steroidal anti-inflammatory drugs (NSAIDs) used in the management of recurring muscle stiffness after training cause stomach ulcers, kidney diseases and heart disorders when taken for a long time (Hayashi *et al*., 2021). Inflammation that takes place after rigorous exercises is central to DOMS and the management of these cytokines has been noted to decrease muscle soreness and pain. Given that the athletic populace and physically active people need routine dosage of pain relievers, the search for safer natural alternatives remains appropriate and relevant. In the light of the present study, it is seen that bromelain has both anti-inflammatory and proteolytic actions, making it a possible candidate. Some studies reported bromelain effectivity in controlling inflammation, which prevents tissue damage and pain in the body after rigorous physical workouts (Bindu *et al*., 2020). This is perhaps a more natural approach to combating inflammation, and more importantly, is safer than the typical use of NSAIDs in the management of DOMS. According to the Inflammation Theory of DOMS, muscle damage from the high intensity exercise triggers an invasion of inflammatory cells that cause pain and stiffness (Peake *et al*., 2017). Bromelain's potentials to modulate this inflammatory response makes it an ideal alternative for post-exercise recovery.

Delayed onset of muscles soreness is a sign of trauma and stress to the muscles of athletes arising from heavy loads on the musculoskeletal system which can be monitored using wearable devices (Pexa *et al*., 2023). DOMS is manifested by tenderness, soreness and inflammation which reach their climax within 24 to 72 post exercise. Common managements are mostly related to NSAIDs and other drug therapies which are deemed to have severe side effects in the long run. It is well noted that even the small decrease in muscle tenderness is beneficial because it keeps athletes in training longer, and minimizes their use of muscle anti-inflammatories that have been associated with negative health consequences. In this they suggest, bromelain has an edge over the other NSAIDs as it takes time to build up its effectiveness, while the later comes with its share of side effects when taken for an extended period. While literature is replete with reports on the role of bromelain as an anti-inflammatory agent, there is paucity of information on its role in reducing post-exercise muscle soreness and its role as an alternative to regular drugs such as NSAIDs.

MATERIALS AND METHODS

Area of Study and Selection of Athletes

The study was conducted within a private fitness facility in Lagos State, Nigeria. Thirty (30) athletes either runners or recreational/professional athletes between the ages of 30-65 were chosen randomly after confirming their health status, health history and had provided informed consent to be part of the study. Participants with history of surgery and current medical treatment were excluded from the study. The experimental group (n=15) comprised of athlete you were placed on bromelain and allowed to apply 1mg/cm² of bromelain cream to the affected muscles daily for seven days post-exercise while the control group (n=15) were athletes applying non-active cream on the affected muscles. Pre-existing conditions were

screened to ensure participants' health did not influence results. Additionally, participants were required to discontinue any use of pain relief medications weeks before the trial.

Exercise protocol

An exercise protocol was designed to induce DOMS consistently across participants using eccentric exercises such as downhill running and resistance training that are widely known to cause the most muscle damage and inflammation compared to concentric movements (Serinken *et al*., 2013). Exercise intensity was standardized to regulate the differences in individual fitness levels and pain tolerance. Baseline assessments was done at the starting point for each participant. Study participants were monitored and prevented from other physical activities during the recovery period that can interfere with muscle soreness or inflammation.

Muscle Soreness Assessment

The method of Lopes-Virella *et al.* (2013) was adopted and modified. Measurements included muscle strength, flexibility and perceived pain levels at baseline and 24, 48 and 72 hours which are peak periods of DOMS symptoms post-exercise and help to capture the full recovery timeline (Bergens *et al*., 2021). We measured pain intensity using a standard tool for quantifying pain called the visual analogue scale (VAS) as described by Martin *et al*. (2013). Perceived muscle stiffness and functional performance were measured using objective tests such as strength and flexibility assessments.

Measurement of Inflammation markers

We measured some serum inflammation biomarkers levels such as CRP and IL-6 using enzyme-linked immunosorbent assay (ELISA), spectrophotometry, and modified Westergren method respectively.

Data Analysis

The data generated from the study was presented as mean ± standard error of the mean of five replicates and subjected to one-way Analysis of Variance (ANOVA). The data was considered statistically different ($p < 0.001$) using GraphPad Prism version 8.01 (GraphPad Software, Inc., San Diego, California, United States).

RESULTS

Reduction in Pain Intensity

The reduction in pain intensity measured by the Visual Analog Scale (VAS) showed a significant decrease ($p<0.001$) in pain intensity of the experimental group compared to the control group at 24-, 48-, and 72-hours post-exercise (Table 1).

Table 1: Visual analog scale pain scores for post-exercise of bromelain and placebo groups based on hours

Time Point (Hrs)	Experiment group (n=15)	Control group (n=15)	P-Value
24	3.1 ± 0.8	5.0 ± 1.2	< 0.001
48	2.4 ± 0.7	4.5 ± 1.1	< 0.001
72	1.6 ± 0.6	3.8 ± 1.0	< 0.001

Values are expressed as Mean±SEM

The experimental group reported a significantly faster reduction in pain intensity compared to the control group ($P < 0.001$ at all-time points).

Reduction in Inflammation Markers

Table 2 showed the serum level of C-reactive protein (CRP) and interleukin-6 (IL-6) at baseline, 24, 48, and 72-hours post-exercise. The result indicated a significant decrease ($p<0.001$) in the inflammation markers in the experimental group compared to the control group, confirming bromelain's anti-inflammatory properties.

Table 2: Inflammation markers (CRP and IL-6) for post-exercise of bromelain and placebo groups based on hours

Time Point (Hrs)	Experimental Group (CRP, mg/L ± SD)	Control Group (CRP, mg/L ± SD)	Experimental Group (IL-6, pg/mL ± SD)	Control Group (IL-6, pg/mL ± SD)	P-Value
Baseline	1.8 ± 0.5	1.9 ± 0.6	4.3 ± 0.9	4.1 ± 0.8	0.89
24	2.0 ± 0.6	3.1 ± 0.7	3.8 ± 0.7	5.3 ± 1.0	< 0.01
48	1.5 ± 0.4	2.9 ± 0.8	3.2 ± 0.6	4.8 ± 0.9	< 0.01
72	1.3 ± 0.3	2.7 ± 0.7	2.7 ± 0.5	4.6 ± 0.8	< 0.01

Values of CRP and IL-6 are expressed in mg/L and pg/mL (Mean±SEM); CRP=C-reactive protein; IL-6=interleukin 6 (n= 15). CRP= C-reactive protein, IL-6= Interleukin-6

The significant reduction in CRP and IL-6 levels in the bromelain group after 24 hours ($P < 0.01$) suggests a rapid anti-inflammatory response.

Muscle Stiffness and Functional Recovery

Table 3 measured muscle stiffness and functional performance. Stiffness was self-reported by participants, while functional performance was measured by strength and flexibility tests. The experimental group showed significant ($p<0.001$) improvements in both areas. Participants in the experimental group reported a significant reduction in stiffness ($P < 0.001$) and improved strength and flexibility over the 72-hour recovery period.

Table 3: Perceived muscle stiffness, strength, and flexibility scores for bromelain and placebo groups.

Time Point (Hrs)	Experimental Group (Stiffness Score)	Control Group (Stiffness Score)	Experimental Group Strength Test (kg)	Control Group Strength Test (kg)	Experimental Group Flexibility Test (cm)	Control Group Flexibility Test (cm)
24	4.1 ± 0.8^a	5.3 ± 1.0^b	78.2 ± 5.3^a	67.5 ± 2.3^b	12.8 ± 2.5^a	9.3 ± 2.1^b
48	3.4 ± 0.7^a	5.0 ± 0.9^b	82.1 ± 4.9^a	63.8 ± 3.6^b	14.1 ± 2.8^a	11.4 ± 2.3^b
72	2.7 ± 0.6^a	4.7 ± 0.9^b	85.5 ± 4.6^a	72.5 ± 1.9^b	16.3 ± 3.1^a	13.1 ± 2.6^b

Values are expressed as Mean±SEM. Values with different alphabet differs significantly ($P < 0.001$) across experimental and control group (n=15)

DISCUSSION

Results from this study is supportive of the use of bromelain as an effective means of decreasing muscle soreness after exercises and increasing the amount of time needed for the recovery. The reduced pain intensity and significantly suppressed inflammation in the experimental group within a short time and the improvement in muscle stiffness and functional performance lends support for the use of Bromelain as an effective natural anti-inflammatory agent other than the conventional Anti-Inflammatory drugs like NSAIDS. According to the findings of this study, the participants who took bromelain for a week made considerable improvements as compared to the control group because it minimized exercises induced soreness, inflammation and stiffness. These results are in accord with the research aim of this work, which was to investigate the effectiveness of bromelain in treatment of DOMS and functional recovery.

What emerged in the findings of our study was that the pain intensity of the experimental group was lower than that of the control group based on the VAS. This decrease in pain

intensity corresponds with other studies on the effectiveness of bromelain in managing muscle pain such as in Majid *et al*. (2014) who postulated that bromelain has an effective anti-inflammatory role in decreasing muscle pain and stiffness. In a placebo-controlled, double-blind study, Majid *et al.* recruited 45 patients and showed that pain scores reduced by thirty percent with the use of bromelain. Our findings supported the growing body of evidence on the potentials of bromelain as an agent to control pain after an exercise.

Our results offered one more positive aspect of bromelain supplementation by evaluating the outcome of inflammation markers. Both CRP and IL-6 were significantly decreased in the experimental group after 24-, 48-, and 72-hours post-exercise. The present study supported the work of Picod *et al.* (2022) that pointed out that Bromelain has the potential to block pro-inflammatory cytokines specifically IL-6 in response to muscle damage. As seen in Picod's study based on athletes, reduced systemic inflammation was another role of bromelain in enhancing athletes' muscle recovery, which supports the present study findings.

However, Del Giudice and Gangestad (2018) noted that, although bromelain successfully limits mild to moderate inflammation, it does not do as well in extreme cases of muscle damage. In their study, when marked by greater levels of muscular damage, little improvement from bromelain was noted as opposed to other anti-inflammatory medications such as NSAIDs with fifty participants. Alternatively, in our study, which included 30 participants characterized by moderate exercise-induced muscle soreness, the effects were shown to be maintained over all time points. This is suggesting that bromelain could be most beneficial in situations of moderate and controlled damage to the muscle hence may not be very effective in cases of severe muscle trauma.

In addition, strengthening the effects of the bromelain, the participants of the exercise group noted an increase in functional performance indicators including strength and flexibility. In the same manner, flexibility enhanced in the experimental group more than the control group. These data suggest that bromelain may not only help in decreasing pain and inflammation but also crucial to allowing the muscle fibres to regain their peak contraction capacity more rapidly. This is in agreement with Arefin *et al*. (2020) because they established that supplementing with bromelain benefited functional recovery after exercise due to improved muscle pump and decreased stiffness. Our study also employed strength and flexibility tests, similarly to that employed by Arefin, who worked with 30 professional athletes in his study. However, data from other studies on other kinds of recovery interventions like cryotherapy or compression garments challenge the uniqueness of bromelain as a recovery treatment. Cryotherapy was reported to be more effective than bromelain supplements in a three-day controlled trial of 25 athletes according to Adnan *et al*. (2018) since it resulted in lower muscle stiffness and quicker increase in strength. In their report, bromelain resulted 10% enhancement in strength at 48 hours while cryotherapy provided 20% increase in strength. Our study however demonstrates bromelain's advantage in terms of reduced inflammation and pain. Thus, while other recovery techniques may provide faster functional improvements, bromelain's benefits across pain, inflammation, and performance make it a versatile recovery alternative

One notable limitation about this study is based on the number of participants used in the study, which was 30 participants only, and this may lead to low generalization of the results. However, looking at the data it is significantly very clear with $P < 0.001$ for pain relief and $P < 0.01$ for inflammation indicators showing that bromelain has potential in relieving DOMS. More extensive research can re-affirm such results and also investigate differences in the quantity, the frequency and the route of administration of such substances.

In general, the observations of the present study bear major consequences to utilizing bromelain in sports medicine and muscle recovery therapy. With the discovery on how bromelain works by reducing pain and inflammation in a short time together with better muscle function, bromelain becomes a supplement that can be taken by athletes or anyone who engages in rigorous exercise. This present study supports earlier clinical findings regarding bromelain's anti-inflammatory and analgesic benefits and highlights its applicability in training environments for athletes.

CONCLUSION

This investigation aimed to examine the effectiveness of bromelain, as a natural supplement, in the prevention of muscle soreness, inflammation, and stiffness and more specifically, presented an evaluation of the use of bromelain in recovery. The principal findings of this investigation stemmed from the observation of a decrease in pain intensity in the experimental group as compared to the control group of the study at all time points subsequent to exercise. Moreover, similar to baseline values, the inflammation markers investigated such as CRP, and IL-6 were reduced in the experimental group compared to the control group with the most significant differences determined at 48 hours post-exercise. Other results revealed that the strength and flexibility of the study participants in the experimental group improved by a greater extent over the 72 hours as compared to the study participants in the control group. Due to its natural non-pharmacological characteristic, bromelain is likely to be applied for various purposes connected with the muscle recovery, pain management, and inflammation modulation. The study offers basis for future investigations thereby may impact on the creation of fresh recovery procedures involving natural compounds such as bromelain.

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