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Effects of a chicken-derived functional drink on high-intensity endurance performance and recovery in amateur cyclists

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ABSTRACT

Background: High-intensity endurance exercise often causes fatigue, muscle damage, and delayed recovery, driving interest in nutritional strategies to enhance performance and recovery. Chicken Essence (CE), a traditional Asian supplement and a chicken-derived functional drink rich in BCAAs, carnosine, anserine, taurine, and essential micronutrients, which may improve muscle buffering, energy metabolism, and reduce oxidative stress. These effects have been associated with improved performance and reduced levels of muscle damage, as indicated by markers such as creatine kinase and lactate. While short-term CE use has yielded mixed outcomes, long-term supplementation may offer more substantial benefits.

Objective: This study aims to investigate the effects of chicken essence (CE) supplementation on physiological alterations, high-intensity endurance performance (HIEP), and post-exercise recovery after HIEP cycling.

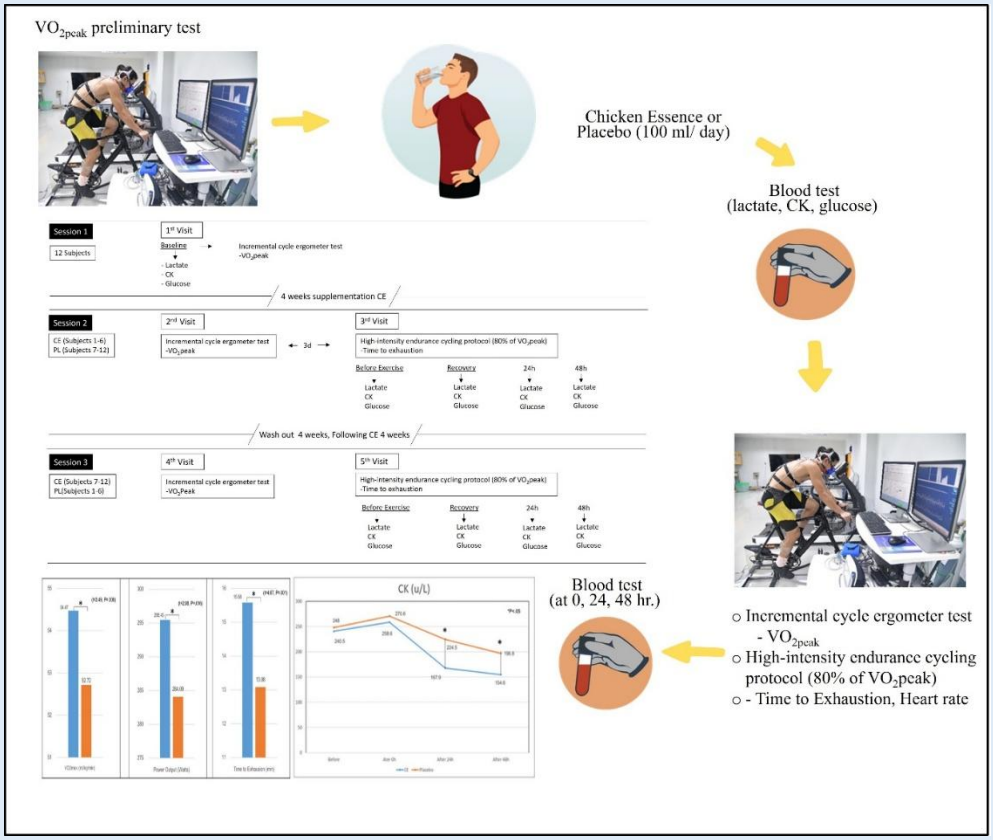
Methods: Twelve healthy, amateur, male road cyclists participated in a randomized double-blind, placebo-controlled, crossover study. The subjects ingested two bottles (100 ml) of CE or a placebo (PL) per day for 4 weeks. In the first session, the subjects underwent a maximal incremental test (VO2peak) using a cycling ergometer to establish a baseline. During the second and third visits, the subjects were tested for VO_{2peak} and then performed a HIEP cycling at 80% VO_{2peak}. Supplementation conditions (CE or PL) were performed, in a random order, after a washout period of 1 month. Then, during the fourth and fifth visits, subjects repeated the VO_{2peak} and HIEP cycling at 80% of their VO_{2peak}. Baseline blood samples were obtained again immediately after the HIEP cycling test and 24 and 48 hours (h) thereafter and analyzed for creatine kinase (CK), blood glucose, and lactic acid.

Results: The maximum oxygen consumption, maximal power outputs, and time to exhaustion varied significantly between the CE and PL groups. The CK level and percentage decrease in lactic acid were significantly different between the CE and PL groups at 24 and 48 h. The blood glucose was significantly different between the CE and PL groups immediately after the HIEP test.

Novelty: This study is the first to investigate the chronic effects of Chicken Essence (CE) supplementation over 4 weeks on high-intensity endurance performance and post-exercise recovery in amateur cyclists using a randomized, double-blind, placebo-controlled, crossover design. Unlike previous studies that focused on short-term supplementation or non-athletic populations, this research provides novel insights into the potential of chicken-derived functional drinks to enhance aerobic capacity, prolong time to exhaustion, and reduce markers of muscle damage, offering evidence for their use as a functional supplement in endurance sports.

Conclusion: These results suggest that ingesting 100 ml/day for 4 weeks increased high-intensity endurance performance and recovery in amateur cyclists.

Keywords: amino acids; chicken essence; cyclist performance; functional drink; maximum oxygen consumption; time to exhaustion; fatigue; muscle damage



Graphical Abstract: Effects of a chicken-derived functional drink on high-intensity endurance performance and recovery in amateur cyclists

INTRODUCTION

Chicken Essence (CE), a traditional remedy widely consumed across Asia, is renowned for its ability to reduce both physical and mental fatigue. As a chicken-derived functional drink, CE contains bioactive components including proteins, dipeptides, free amino acids, particularly carnosine and anserine, as well as taurine, a range of essential minerals, trace elements, and vitamins. Carnosine and anserine, two naturally occurring dipeptides, have been shown to exert beneficial effects on muscle function and metabolism [1,2]. Studies indicate that prolonged ingestion of chicken breast extract, rich in these dipeptides, over 30 days significantly increases muscle carnosine concentrations in humans [3]. The physiological benefits associated with CE consumption are multifaceted. Research suggests that the increased carnosine levels contribute to enhanced performance during high-intensity exercise, primarily by improving muscle buffering capacity, which helps to delay the onset of fatigue [4]. Furthermore, CE has been linked to a reduction in muscular fatigue [5] and a decrease in blood pressure [6], which may be attributed to the combined effects of its amino acids, taurine, and other bioactive compounds. These nutrients may also work synergistically to support cellular hydration, improve energy metabolism, and mitigate oxidative stress. Additionally, CE's ability to act as a buffering agent in muscles helps to maintain optimal pH levels during intense physical activity, thus preventing the detrimental effects of acidosis [7] Collectively, these effects highlight the potential of CE as a functional food supplement, with its nutrient components working in concert to promote physical performance, enhance recovery, and improve overall health [8].

Amino acids, particularly branched-chain amino acids (BCAAs) including leucine, isoleucine, and valine, have been shown to enhance athletic performance through several mechanisms. These include optimizing energy utilization during exercise, reducing mental fatigue, and mitigating the effects of overtraining [9]. Additionally, BCAAs play a crucial role in maintaining proper neurological function and regulating blood glucose and insulin levels [10–11]. Supplementing with BCAAs has been found to alleviate fatigue [12-13], reduce perceived exertion during exercise [14], and enhance overall exercise performance [15]. Beyond BCAAs, other amino acids, such as L-alanine, also serve as energy sources during endurance exercise, improving efficiency and delaying the onset of muscle soreness following prolonged physical activity [16]. Consequently, the CE (50 mL) in one bottle of this study contained 1,110 mg of amino acids and dipeptides, of which leucine, lysine, and alanine may increase acetyl-CoA, arginine may increase α-ketoglutarate, and isoleucine and valine may increase succinyl-CoA availability. These amino acids and dipeptides may raise the concentration of oxaloacetate in the Krebs cycle (i.e., during fasting or prolonged physical activity) [17]. Additionally, the presence of carnosine and anserine in CE enhances intracellular buffering capacity, optimizes H+ ion control, and improves calcium handling in muscle cells [4], which may contribute to an intense buffering action and maintenance of optimal pH for enzyme function during high-intensity exercise.

CE supplementation has been shown to reduce lactate levels during the recovery phase following a single bout of exercise [18]. In a rat model, CE supplementation for 4 weeks also significantly lowered lactate and creatine kinase (CK) levels after exercise [19]. Additionally, CE has been reported to alleviate mental fatigue in both healthy men [20] and workers under stress [21]. Another study on cyclists found that CE supplementation for 7 days did not enhance cycling performance [22]. However, there is not enough research on chronic CE supplementation in cyclists. Therefore, the primary aim of the present investigation was to assess the effects of CE

supplementation on physiological changes, high-intensity exercise performance (HIEP) in cycling, and post-exercise recovery. This was achieved by administering a daily dose of 100 mL of CE for 4 weeks.

METHODS

Participants: Twelve healthy, male, amateur road cyclists aged 31–43 years, height 173.72 ± 5.55 cm, weight 69.75 ± 8.32 kg were recruited based on cycling at least 120 km per week for at least 6 months. The participants were evaluated using a questionnaire. All participants had a baseline VO2peak value greater than 40 mL/kg/min. The exclusion criteria encompassed significant cardiovascular disease risks, musculoskeletal injuries, smoking, and the use of any medication or protein/amino acid supplement within the preceding 6 months. The participants were advised to maintain their dietary routine, abstain from additional supplements during the study period, maintain all training, and refrain from drinking alcohol and caffeine-containing beverages on the day before testing. After undergoing a medical health screening, all participants provided written informed consent to participate in the study, which was approved by the Ethics Committee of Kasetsart University, Thailand.

Study design: Twelve healthy amateur road cyclists participated in a double-blind, placebo-controlled, crossover nutritional intervention study at the Cardiometabolic Laboratory, Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom, Thailand. The participants were tested for maximal incremental oxygen uptake (VO2peak) using a HIEP cycling protocol, as outlined in the study design overview in Figure 1, which consisted of three different sessions spanning five visits during the trial. Supplementation conditions (CE or placebo) were administered in a random order, followed by a 1-month washout period and then another month of intake. An independent researcher allocated participants to the CE or PL conditions. The subjects fasted for 10 hours before the tests and drank 50 mL of CE or the PL 30 min before blood sampling or testing. The testing lasted from 6:00 a.m. to 11:00 a.m. (Figure 1.)

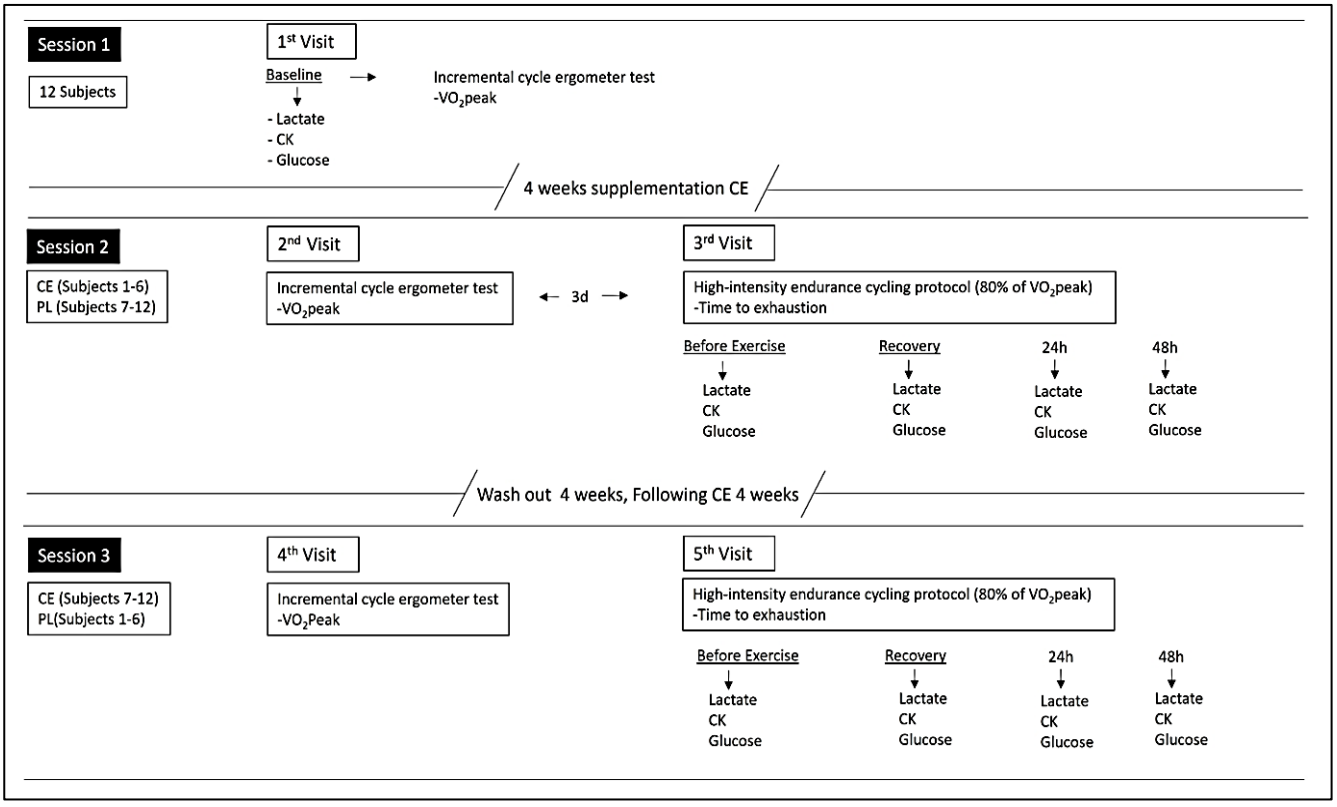


Figure 1. Schematic of experimental procedures.

As shown in Figure 1, the study was structured into three sessions, each with multiple testing visits. Session 1 served as the baseline phase, during which all 12 subjects underwent their first visit for initial assessments. During this session, participants completed an incremental cycle ergometer test to determine their VO2peak, which established their fitness levels. Baseline measurements were taken for lactate, creatine kinase (CK), and glucose levels to establish pre-intervention values. Following these baseline assessments, subjects began a 4-week supplementation period with CE. Session 2 represented the first experimental phase of the crossover design, where subjects were divided into two groups: the CE group (subjects 1-6) and the PL group (subjects 7-12, where PL likely represented placebo. The second visit involved another incremental cycle ergometer test measuring VO_{2peak}. After a 3-day interval, the third visit took place, featuring a high-intensity endurance cycling protocol performed at 80% of each participant's VO_{2peak}, with time to exhaustion being the primary performance measure. Comprehensive physiological measurements were collected at multiple time points: before exercise, immediately, at 24 and 48 hours after the HIEP test (lactate, CK, and glucose). Following Session 2, participants entered a 4-week washout period to eliminate any residual effects from the initial supplementation, followed by another 4 weeks of supplementation during which the groups switched treatments. **Session 3** implemented the crossover component of the study design, where subjects 7-12 received CE supplementation while subjects 1-6 received placebo treatment. The fourth visit mirrored the procedures of the second visit with incremental cycle ergometer testing. The fifth visit replicated the protocol of the third visit, involving the same high-intensity endurance cycling test at 80% VO2peak, with identical measurement schedules at all time points. This crossover design ensured that each participant served as their control, allowing for more robust statistical analysis and reducing inter-individual variability in the assessment of CE supplementation effects on cycling performance and recovery markers.

Intervention: The Chicken Essence (CE) and placebo (PL) supplements were provided by the CPF Food Research and Development Center. The CE supplement was prepared using an enzymatic digestion process. The amino acid and dipeptide composition of the CE supplement was analyzed using LC-MS/MS on an LC-MS/MS-8060 system (Shimadzu, Japan). Amino acid concentrations were determined by comparing the sample chromatograms with standard curves for each compound. Each 50 mL bottle of CE contained 1,110 mg of amino acids and dipeptides, with the three most abundant amino acids being leucine (135 mg), lysine (122.5 mg), and arginine (100 mg), as shown in Table 1. The dipeptides included 150.5 mg of β-alanyl-L-methyl-L-histidine (anserine) and 83.5 mg of carnosine (β-alanyl-L-histidine). The zero-calorie PL was composed of 99% water and 1% coloring and flavoring agents. Both the CE and PL were designed to have similar packaging, appearance, and taste. Participants were instructed to consume one bottle of either CE or placebo twice daily (before breakfast and dinner) for 4 weeks.

The time interval between each intake period was 4 weeks as a washout period. During each intake and washout period, participants maintained their physical activities and cycling training volume while continuing to follow their normal dietary behavior, drinking patterns, and sleeping habits.

Table 1. Amino acid profiles in chicken essence

Amino acid profiles	Free amino acid (mg/100g)	Free amino acid (mg/bottle)
L-Aspartic acid	71	35.5
L-Glutamic acid	89	44.5
L-Threonine	63	31.5
L-Serine	63	31.5
L-Alanine	122	61.0
L-Asparagine	33	16.5
L-Glutamine	5	2.5
L-Proline	39	19.5
Glycine	32	16.0
L-Valine	83	41.5
L-Methionine	72	36.0
L-Leucine	270	135.0
L-Isoleucine	81	40.5
L-Lysine	245	122.5
L-Phenylalanine	112	56.0
L-Histidine	54	27.0
L-Tryptophan	24	12.0
L-Tyrosine	51	25.5
L-Arginine	201	100.5
L (-)-Cystine	5	2.5
Beta-Alanine	10	5.0
Taurine	24	12.0
L-Ornithine	2	1.0
Sarcosine	<1	<.5
4-Aminobutyric acid	<1	<.5
Anserine	301	150.5
Carnosine	167	83.5
Total amino acids (mg/100g)	2,220	1,110

Measurements

Incremental test: The participants underwent an incremental exercise test to exhaustion on a cycle ergometer (CYCLUS2 Ergometer; RBM Electronics, Leipzig, Germany) to determine their VO_{2peak} values and maximal power outputs using the Astrand cycle ergometer maximal test protocol [23]. The initial power output was 100 W for 5 min, with an increased power output every 3 min in increments of 50 W. All subjects continued increasing the power output until volitional exhaustion. The test was considered valid when at least two of the following criteria were met: (a) plateauing of VO_2 while increasing work rate (increase of no more than 2 mL/kg/min) [24], (b) a respiratory exchange ratio (RER) greater than 1.1, and (c) a heart rate (HR) within 10 beats/min of the predicted maximum (220 age beats/min) [25] and rate of perceived exertion (RPE) greater than 17 (6–20 scale). Breath-by-breath expired air measurements were performed throughout the test using a gas analysis system (Stationary gas analyzer, Gas

analyzer; Vmax Encore® Metabolic Cart; Vyaire Medical Inc.; Yorba Linda, CA, USA). The value used for VO_{2peak} corresponded to the highest value achieved over a 30-second sampling period.

High-intensity endurance performance test: After a 5-minute warm-up at 60 W, participants cycled to volitional exhaustion on a cycle ergometer at a workload that elicited 80% of their VO_{2peak} (at 80–90 rpm). The test was terminated when the pedal cadence dropped below 75 rpm for more than 5 seconds or when the participants voluntarily stopped cycling. The exercise duration covered was recorded for time to exhaustion, and HR was monitored continuously throughout the test. Blood samples were taken immediately and at 24 and 48 h after the completion of the HIEP test for determination of CK, glucose, and lactic acid levels.

Blood sampling: Following fasting for 10 h, a trained, registered nurse performed a venipuncture procedure from 6 a.m. to 11 a.m. to obtain a blood sample (5 mL) from the antecubital vein of the subject for CK and glucose analysis. Blood samples were taken on the test day after participants drank a bottle of CE for 30 minutes, immediately after the HIEP test, and then at 24 and 48 hours thereafter. The blood samples were analyzed at BK Lab Health Center (Nakhon Pathom, Thailand) for CK and glucose using the kinetic enzymatic method, chemiluminescence immunoassay, electrical impedance, and light scattering methods. A fingertip blood sample was taken for lactic acid analysis using a Lactate Scout, EKF diagnostics, US. Samples were taken after drinking a bottle of CE for 30 minutes, during exercise for 10 minutes, and immediately after the HIEP test, and then again 24 and 48 hours later.

Dietary Controls: The participants were encouraged to maintain their normal food intake levels throughout the experiment. Nutrition logs were monitored, and data collected. Participants completed a 3-day food diary before and after the 4-week intervention to track changes. In addition, their recorded dietary, energy, and macronutrient intakes were analyzed using the INMUCAL V.3 software (Institute of Nutrition, Mahidol University, Nakhon Pathom, Thailand).

Statistical analysis: The results were presented as the mean and standard deviation (SD). The Shapiro-Wilk test was used to determine whether the data were normally distributed. A two-way analysis of variance with repeated measures was used to determine the effects of CE, placebo, and time on the dependent variables. For significant interactions or main effects, post hoc analysis was performed using the Bonferroni method with statistical significance set at $p<0.05$. Statistical analyses were conducted using the SPSS software 26.0 for Windows (SPSS Inc., Chicago, IL, USA). Changes in lactic acid and central fatigue during the recovery period were expressed as percentages at the end of the recovery period relative to immediately after: Decreased percentage (%) = [(Data during recovery period - Data immediately after) / Data immediately after] x 100%.

RESULTS

Training volume and daily energy intake: The characteristics of the participants are shown in Table 2. The training volume remained relatively constant over time, and no significant differences were found between trials. The CE trial had meant total time and total distance training of 1110.91 ± 886.36 min and 534.76 ± 435.14 km, respectively, while the PL trial values were 1171.68 ± 802.78 min and 525.31 ± 420.96 km, respectively The average energy intake during the experiment did not differ significantly between the CE and PL trials, with values of 1713.49 ± 676.22 and 1634.34 ± 550.69 kcal/day, respectively, as shown in Table 3.

Table 2. Characteristics of participants.

Variable	Mean ± SD	Range
Age (yr)	37.36 ± 4.69	31.00–43.00
Height (cm)	173.72 ± 5.55	165.00–183.0
Body mass (kg)	69.75 ± 8.32	58.00–83.00
Body mass index (kg/m²)	23.11 ± 1.81	21.30–24.92
BF (%)	17.90 ± 4.37	11.30–25.30
Baseline VO_{2peak} (mL/kg/min)	50.82 ± 5.31	42.00–57.00
Resting HR (beats/min)	61.00 ± 5.32	51.00–66.00
Resting SBP (mmHg)	124.81 ± 6.94	113.00–135.00
Resting DBP (mmHg)	80.72 ± 7.49	71.00–97.00
Creatine kinase (μ/L)	179.00 ± 94.98	98.00–326.00
Blood sugar (mg/mL)	92.90 ± 4.01	87.00–99.90

SD, standard deviation; BF, body fat; HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; VO_{2peak}, peak oxygen consumption.

Table 3. Training volume and Dietary intake of CE and placebo groups.

Training volume and Dietary intake	CE	PL	*P*-value
Training volume			
Total time (min)	1,110.91 ± 886.36	1,171.68 ± 802.78	.880
Total distance (km)	534.76 ± 435.14	525.31 ± 420.96	.760
Dietary intake			
Energy intake (Kcal/day)	1713.49± 676.22	1634.34 ± 550.69	.870
Carbohydrate (g)	175.24 ± 36.52	197.8 ± 60.37	.420
Fat (g)	67.32 ± 30.43	54.39 ± 28.56	.660
Protein (g)	101.67 ± 85.67	88.40 ± 31.43	.740
Proportional distribution of nutrients (%)			
Carbohydrate	43.84 ± 11.16	48.93 ± 7.00	.370
Fat	35.45 ± 5.39	28.66 ± 7.27	.260
Protein	20.71 ± 10.37	22.40 ± 8.46	.580

In the CE trial, carbohydrate, fat, and protein accounted for approximately 43%, 35%, and 20%, respectively, of the daily energy intake, compared to approximately 48%, 28%, and 22%, of daily energy intake in the PL trial, as shown in table 3.

High intensity endurance performance: The VO2peak, maximal power outputs, and time to exhaustion were significantly different between the CE and PL trials, as shown in Figure 2. The CE and PL trials had mean VO2peak values of 54.47 ± 7.39 and 284.09 ± 20.22 mL/kg/min, respectively, mean maximal power outputs of 295.45 ± 24.54 and 52.72 ± 6.83 W, respectively, and mean time to exhaustion of 15.58 ± 3.96 and 13.80 ± 3.36 min, respectively.

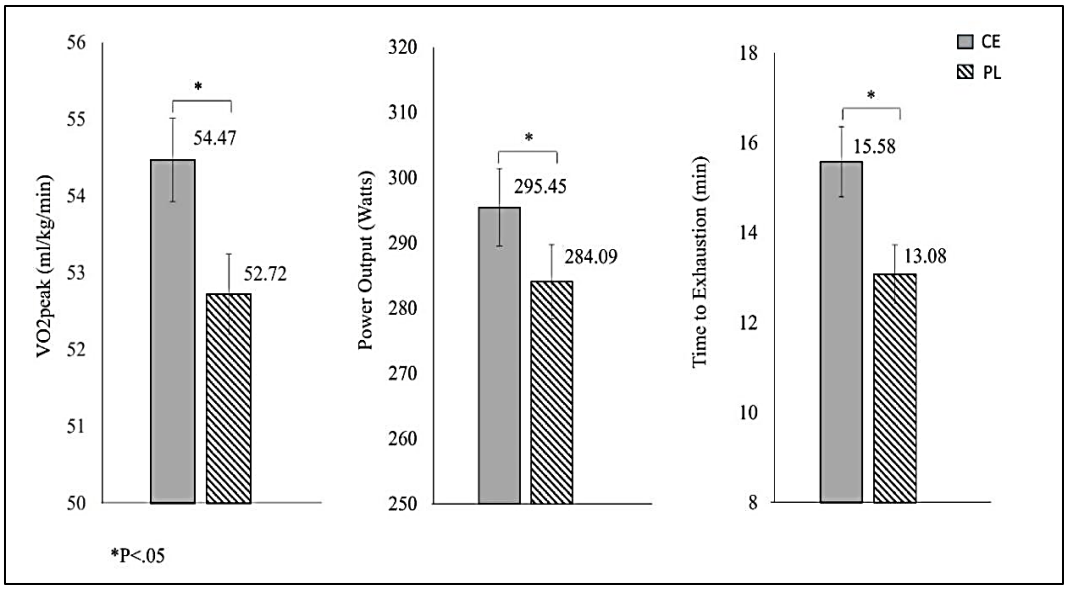


Figure 2. VO_{2peak}, maximal power output, and time to exhaustion after receiving CE or placebo for 4 weeks

Recovery after high-intensity endurance performance: The plasma CK levels changed over time in both trial groups. The CK level of subjects increased after the HIEP test and reduced after 24 h and 48 h in both trials. There was a significant difference between the CE and placebo groups at 24 h and 48 h. In addition, the plasma CK levels at 24 h and 48 h in the CE group were significantly lower than in the placebo trial, as shown in Figure 3.

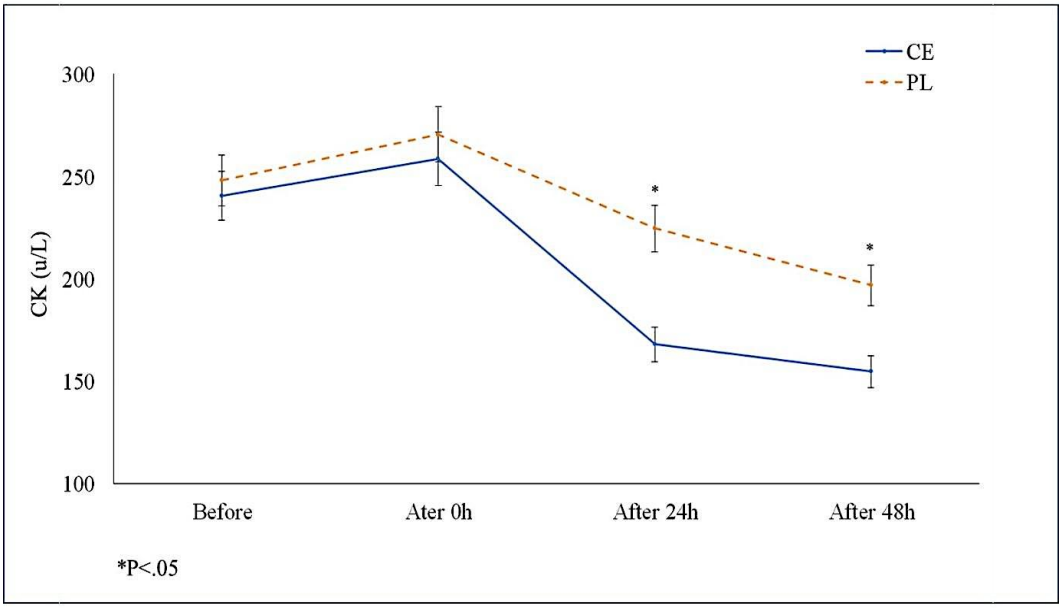


Figure. 3 CK at baseline and at 0 h, 24 h, and 48 h after high-intensity endurance test.

The blood glucose levels increased after the HIEP test and then decreased after 24 and 48 hours in both trials. There was a significant difference between the CE and placebo groups immediately after the HIEP test.

The blood glucose levels for the CE group were higher than for the placebo trial, as shown in Figure 4. However, there were no significant differences between the 24- and 48-hour groups.

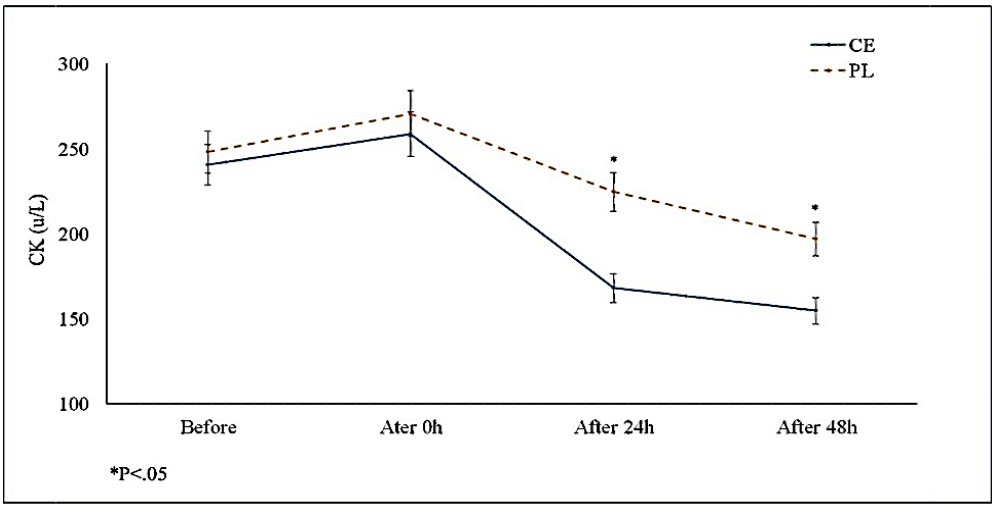


Figure 4. Blood glucose at baseline, 0 h, 24 h, and 48 h after high-intensity endurance test.

The lactic acid level was not significantly different at any of the recovery time points for either group, as shown in Table 4. There was a greater reduction in plasma lactic acid in the CE group than the PL group, with decreases at 24 h of 88.04% and 81.58% for the CE and PL groups, respectively, and at 48 h of 92.37% and 86.11 % for the CE and PL groups, respectively, as shown in Figure 5.

Table 4 Lactic acid at baseline, immediately after high-intensity endurance test, and at 24 h and 48 h thereafter.

	CE (mean ± SD)	Placebo (mean ± SD)	t	p-value
Baseline (mmol/l)	1.54±.54	1.74±.59	-.86	.408
0 h after (mmol/l)	12.00±1.48	11.60±1.97	.61	.550
24 h after (mmol/l)	1.70±.34	1.80±.57	-.53	.607
48 h after (mmol/l)	1.43±.32	1.60±.30	-1.12	.289
Decrease after 24 h (%)	88.04 ± 3.14	81.58 ± 2.19	8.31	.000**
Decrease after 48 h (%)	92.37 ± 2.92	86.11 ± 2.25	6.20	.000**

** = p<0.01

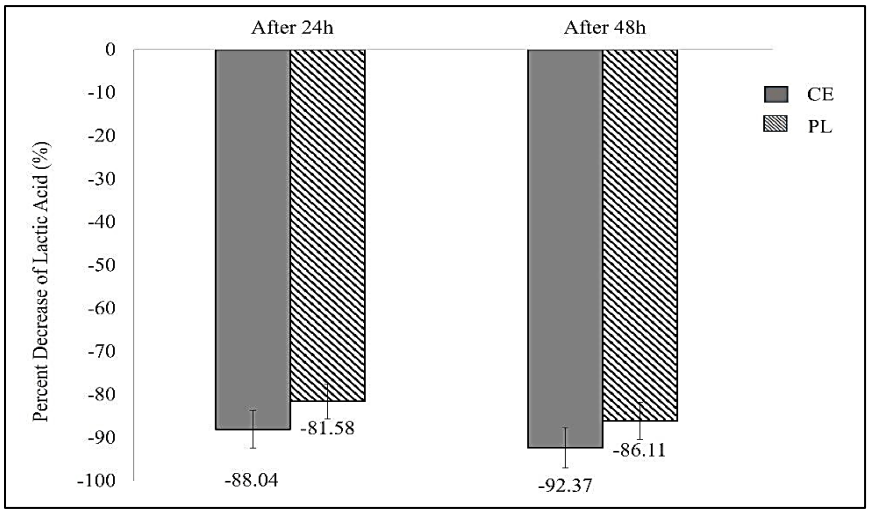


Figure 5. The percentage of lactic acid decreased after 24 h and 48 h.

DISCUSSION

The present results demonstrated that supplementation with CE significantly increased maximum oxygen consumption, maximal power output, and time to exhaustion compared to the placebo (PL). These findings suggest that CE supplementation, when combined with regular exercise, can improve endurance performance. The observed benefits are likely attributable to the synergistic effects of the various bioactive components in CE, rather than the action of a single ingredient.

Previous studies demonstrated that prolonged administration of β-alanine, an amino acid component, leads to elevated levels of muscle carnosine [2]. This rise in carnosine concentration has been found to enhance performance during high-intensity exercise [4]. Another study demonstrated that prolonged consumption of chicken breast extract, containing carnosine and anserine, over 30 days leads to an elevation in muscle carnosine levels in individuals [3]. The cyclists in this study consumed two bottles of CE per day for 4 weeks. The subjects fasted for 10 hours before the tests and drank 50 mL of CE before blood sampling or testing. The Maximum oxygen consumption, reflecting aerobic capacity, suggests that CE supplementation, due to its amino acid composition and putative bioactive characteristics, likely improves VO_2peak via multiple physiological mechanisms. Arginine in CE augments nitric oxide (NO) production through the enzyme nitric oxide synthase (NOS). Nitric oxide induces vasodilation, enhancing blood flow and oxygen supply to active muscles [26]. Leucine, lysine, alanine, arginine, isoleucine, aspartic acid, glutamic acid, and valine in the citric acid cycle enhance the synthesis of NADH and $FADH_2$, which energize the electron transport chain and optimize ATP production during aerobic exercise. The maximal power output and time to exhaustion improved because, during HIEP, the breakdown of ATP and anaerobic glycolysis generates hydrogen ions, which lower intracellular pH, resulting in muscular acidosis. Carnosine and anserine function as intracellular buffers by binding to and neutralizing hydrogen ions, so preserving pH homeostasis [26]. This postpones the onset of acidosis, which would otherwise hinder muscular contraction and diminish exercise performance. This improves the excitation-contraction coupling of muscle fibers, sustaining power output and prolonging exhaustion during high-intensity exercise performance [2].

Previous studies have also highlighted the role of antioxidant supplementation in reducing oxidative stress, muscle fatigue, and improving exercise performance [27]. CE contains a complex blend of bioactive peptides and amino acids, many of which possess antioxidant properties, suggesting that these compounds may contribute to its observed effects on exercise performance. Notably, several amino acids—such as glutamate, aspartate, histidine, tryptophan, tyrosine, and branched-chain amino acids (BCAAs), including leucine, isoleucine, and valine—are known for their antioxidant properties. These amino acids help mitigate oxidative damage during exercise, thereby reducing fatigue and enhancing recovery. Additionally, essential sulfur-containing compounds in CE, including cysteine, methionine, and taurine, may further contribute to its antioxidant and muscle-protective properties. CE also contains the dipeptides carnosine and anserine, both of which have been shown to impact exercise performance positively. One study reported that carnosine and anserine supplementation enhanced exercise performance by improving muscle buffering capacity and delaying the onset of fatigue [4]. Other studies have reported that CE supplementation promotes muscle cell growth and enhances muscle protein synthesis in vitro. In vivo, CE was shown to improve muscle mass and strength in animal models, highlighting its potential as an effective ergogenic aid. These findings suggest that CE could support muscle development and improve performance, especially in endurance capacity and grip strength [5,28].

Given the variety of bioactive peptides and amino acids present in CE, it is likely that the improvement in endurance performance results from the complex interaction of these components, working together to optimize energy metabolism, reduce muscle damage, and enhance recovery. Further research is needed to understand better the specific mechanisms through which CE exerts these beneficial effects. Studies investigating the roles of individual bioactive peptides and amino acids, such as carnosine and anserine, as well as L-alanine, are warranted. For example, L-alanine has been shown to play a role in preventing energy depletion during exercise by supporting the process of gluconeogenesis. This process produces glucose from amino acids during prolonged physical activity. This mechanism helps preserve energy stores and may contribute to the enhanced endurance observed with CE supplementation [16,29]. Overall, the biological activity of CE appears to result from a multifaceted interaction between its diverse amino acids, peptides, and other bioactive compounds. While the current study provides valuable insights into the potential of CE as an ergogenic aid, further studies are necessary to elucidate the precise mechanisms underlying its effects on exercise performance and recovery.

The levels of CK concentration after 24 and 48 hours of HIEP testing in the CE trial were significantly lower than those in the placebo trial. Another study reported an increase in CK as an indicator of delayed onset muscle soreness, because it inhibits the function of the sarcolemma, causing CK to be released into the bloodstream [30]. The present results were consistent with another study showing that BCAA supplementation (including isoleucine, leucine, and valine) for 8 weeks in male students post-training delayed the onset of muscle soreness, with CK decreasing significantly in the BCAA-drinking group 24 and 48 h after exercise, compared to the placebo group [31]. There are several theories explaining why BCAA supplementation helps to reduce the delayed onset of muscle soreness. When taken before aerobic exercise, BCAAs increase the concentration of growth hormones and lower testosterone, resulting in an anabolic environment [15]. The decrease in amino acids in the muscle during prolonged exercise may cause signals that promote the breakdown of muscle proteins [32]. The replenishment of these proteins requires maintaining high levels of amino acids, which can be achieved by taking BCAA supplements. These supplements may reduce the signaling for muscle protein breakdown or speed up recovery. Therefore, CE, which contains many amino acids (especially leucine, isoleucine, and valine), can help to reduce muscle soreness after HIEP. Another possible mechanism might be that carnosine and anserine act as antioxidants, neutralizing reactive oxygen species (ROS) that can damage the phospholipid bilayers of muscle cell membranes during intense exercise. By preventing oxidative damage, carnosine and anserine help maintain membrane integrity, reducing CK leakage [26]

In addition, the blood sugar level after testing to exhaustion in the CE trial was significantly higher than in the placebo trial. Exercise stimulates the body to increase sugar levels by breaking down glycogen through glycolysis to produce energy [27]. The increased glucocorticoid from protein intake (as amino acid from CE) increases blood sugar [33]. Furthermore, another study using mice that had consumed 5% chicken soup extract for seven consecutive days reported that carnosine stimulated high blood sugar, possibly because the body remained in a state of continued starvation until its glycogen was depleted. Therefore, the protein was broken down to produce amino acids as intermediate substances in the Krebs cycle [34]. The carbon skeleton created by the transamination reaction serves as an intermediate for the formation of glucose through the gluconeogenesis process. Amino acids that are converted to glucose (glucogenic amino acids) include alanine, glycine, cysteine, serine, arginine, proline, histidine,

glutamine, methionine, valine, aspartate, and asparagine. The CE in the present study contained varying amounts of alanine, glycine, serine, arginine, histidine, methionine, and valine, which may have resulted in higher blood sugar levels after consuming the CE compared to the PL [5,16]. This finding is consistent with previous studies that have shown low-molecular-weight peptides derived from chicken are rapidly absorbed, leading to an early increase in circulating glucogenic amino acids and promoting gluconeogenesis shortly after ingestion [35]. After CE supplementation, the lactic acid concentration in the blood increased at 10 minutes and exhaustion for both conditions, with the concentration levels being slightly higher than those of the PL group at the exact times, although not significantly so. However, after 24 and 48 h of exercise, the lactic acid concentrations decreased to normal values in both trials. An increase in lactic acid is associated with an increase in blood glucose. Therefore, cyclists with high workloads utilize energy by burning glucose as their primary energy source, resulting in increased lactic acid, which indicates that the body is relying on an anaerobic energy system. After exhaustion, the percentage decreases in lactic acid concentration in the blood after 24 and 48 h for the CE trial was significantly faster than for the PL trial, with decreases of 88.04% and 92.37% at 24 and 48 h, respectively, compared to 81.58% and 86.11%, respectively, in the PL group (Figure 2). The plasma lactate differences at 24 and 48 h between the CE and PL groups were significantly different, indicating that CE supplementation reduced lactate accumulation. This study showed that CE supplementation increased the rate of lactate removal during recovery from HIEP. The buildup of lactate in the blood was a response to anaerobic exercise, with the level of lactate serving as an indicator of physical fatigue due to the accumulation of lactate and an increase in hydrogen concentration in the muscles [36]. The high concentration of hydrogen results in a decrease in phosphocreatine [37], leading to an increase in ADP and a low pH, which in turn inhibits local muscle contraction [36]. Carnosine (β-alanyl-L-histidine) as an active peptide component in CE can be a pH buffer that acts as a hydrogen ion carrier, neutralizing the lactic acid produced in muscles [38] and perhaps plays a role in reducing muscle fatigue and facilitating recovery. These findings align with recent reviews that highlight the importance of nutritional supplementation in optimizing athletic performance and recovery [39-40].

CONCLUSION

In conclusion, 4 weeks of CE supplementation resulted in significant improvements in maximum oxygen consumption, maximal power output, and time to exhaustion. Additionally, CE supplementation reduced creatine kinase (CK) levels, indicating a decrease in muscle damage, and produced a greater reduction in lactic acid following high-intensity endurance performance (HIEP). These findings suggest that CE may enhance endurance performance and facilitate recovery after high-intensity exercise. However, further studies are needed to evaluate whether CE supplementation can sustain or improve performance during prolonged continuous endurance exercise.

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