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To chew or not to chew? Assessing the differences between chewing and swallowing arugula extract capsules on plasma nitrate levels, blood pressure, and heart rate

Submission date
04/11/2026

Recruitment status
No longer recruiting

Registration date
09/11/2026

Overall study status
Completed

Last Edited
09/11/2026

Condition category
Nutritional, Metabolic, Endocrine

[_] Prospectively registered
[X] Protocol
[_] Statistical analysis plan
[_] Results
[_] Individual participant data
[X] Record updated in last year

Plain English summary of protocol

Background and Study Aims
Nitric oxide is an important molecule that helps regulate blood vessel function and blood pressure. Dietary nitrate, which is naturally present in vegetables such as arugula, can be converted into nitric oxide through processes involving bacteria in the mouth and subsequent reactions within the body. This study aimed to investigate whether chewing arugula extract capsules before swallowing them produces different physiological responses compared with swallowing the capsules whole. Specifically, the researchers sought to examine changes in blood nitrate and nitrite concentrations, blood pressure, and resting heart rate following supplementation.

Who can participate?
The study recruited 12 metabolically healthy adult males between 18 and 50 years of age. Participants were required to be nonsmokers without diagnosed cardiovascular, metabolic, or other chronic diseases. Individuals taking medications that could influence blood pressure, heart rate, or related physiological responses were excluded.

What does the study involve?
Each participant completed approximately four visits over a period of 3 weeks, depending on scheduling and the required washout periods.Participants completed an initial screening and orientation visit, which included informed consent, a review of medical history, and a body composition assessment using dual-energy X-ray absorptiometry (DXA).
Following this visit, participants completed three experimental conditions in a randomized, counterbalanced order:
1. Chewing arugula extract capsules before swallowing.
2. Swallowing arugula extract capsules whole.
3. Completing a control condition without supplementation.
Each condition was separated by a washout period of at least 72 hours. During each experimental visit, blood samples were collected before the intervention and at 1, 2, and 3 hours

afterward. Blood pressure and heart rate were also assessed throughout the testing period. Blood samples were subsequently analyzed to assess circulating nitrate, nitrite, and related markers of nitric oxide metabolism.

What are the possible benefits and risks of participating?
Participants were provided with information about their body composition and general health assessments. However, direct health benefits from participation were not guaranteed. Potential risks included minor discomfort, bruising, or irritation associated with blood sampling, temporary discomfort during blood pressure measurements, and possible mild gastrointestinal discomfort following arugula extract consumption. The DXA assessment also involved a small amount of radiation exposure.

Where is the study run from?
Baylor University (USA)

When is the study starting and how long is it expected to run for?
March 2023 to April 2024

Who is funding the study?
The research was supported by a Baylor University (USA) and a donation of arugula extract supplements from Rucola Health.

Who is the main contact?
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Contact information

Type(s)
Public, Scientific, Principal investigator

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Study information

Scientific Title

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Study objectives
The primary objective of this study was to investigate the effects of chewing versus swallowing arugula extract capsules on circulating nitric oxide metabolites, including total nitric oxide metabolites (NOx), nitrate, and nitrite, in apparently healthy adult males.

Secondary objectives were to evaluate the effects of these administration methods on systolic blood pressure, diastolic blood pressure, and resting heart rate over a 3-hour post-consumption period.

The study also sought to determine whether chewing arugula extract capsules would produce a more rapid increase in circulating nitric oxide metabolites compared with swallowing capsules intact.

Ethics approval required
Ethics approval required

Ethics approval(s)
Approved 17/02/2023, Baylor University Institutional Review Board (Office of the Vice Provost for Research, Baylor University, One Bear Place, Waco, 76798, United States of America; +1 (0) 254-710-3708; irb@baylor.edu), ref: 2015974

Primary study design
Interventional

Allocation
Randomized controlled trial

Masking
Open (masking not used)

Control
Active

Assignment
Crossover

Purpose
Basic science

Study type(s)

Health condition(s) or problem(s) studied
Nitric oxide metabolism, blood pressure, and resting heart rate

Interventions
This study employed a randomized, open-label, three-condition crossover design involving 12 apparently healthy adult males between 18 and 50 years of age.

Participants completed an initial screening visit involving a health history assessment, anthropometric measurements, body composition assessment using dual-energy X-ray absorptiometry (DXA), and baseline blood collection.

The order of experimental conditions was determined using a free, web-based randomization tool. Participants were randomly assigned to intervention sequences involving the three experimental conditions (chewing, swallowing, and control) to minimize potential order effects.

1. Chewing (CW): Participants chewed two arugula extract capsules containing a total of 1,000 mg of arugula extract and approximately 100 mg of dietary nitrate (50 mg per capsule) before swallowing.
2. Swallowing (SW): Participants swallowed two arugula extract capsules intact, containing a total of 1,000 mg of arugula extract and approximately 100 mg of dietary nitrate.
3. Control (CON): Participants received no arugula extract supplementation.

Each experimental condition was separated by a minimum 72-hour washout period. Blood samples, blood pressure, and resting heart rate were assessed at baseline and at 1, 2, and 3 hours during each condition.

Blood samples were analyzed to determine circulating total nitric oxide metabolites, nitrate, and nitrite concentrations. Systolic blood pressure, diastolic blood pressure, and resting heart rate were also assessed throughout the experimental period.

Participants were instructed to maintain consistent dietary intake and physical activity before each experimental condition to minimize potential confounding effects.

Intervention Type
Supplement

Primary outcome(s)
1. Total nitric oxide metabolites (NOx): plasma total nitric oxide metabolite concentration measured using a colorimetric assay at baseline (0 hours), 1 hour, 2 hours, and 3 hours following the intervention

2. Plasma nitrate concentration (NO_3) measured using total nitric oxide metabolites minus nitrite concentration at baseline (0 hours), 1 hour, 2 hours, and 3 hours following the intervention

3. Plasma nitrite concentration (NO_2) measured using a colorimetric assay at baseline (0 hours), 1 hour, 2 hours, and 3 hours following the intervention

Key secondary outcome(s)
1. Systolic blood pressure measured using noninvasive blood pressure assessment at baseline (0 hours), 1 hour, 2 hours, and 3 hours following the intervention

2. Diastolic blood pressure measured using noninvasive blood pressure assessment at baseline (0 hours), 1 hour, 2 hours, and 3 hours following the intervention

3. Resting heart rate measured using heart rate monitoring at baseline (0 hours), 1 hour, 2 hours, and 3 hours following the intervention

Completion date

08/04/2024

Eligibility

Key inclusion criteria
1. Male participants between 18 and 50 years of age
2. Non-smokers
3. No previously diagnosed or known chronic or cardiometabolic diseases
4. Considered apparently healthy according to American College of Sports Medicine (ACSM) guidelines
5. Not currently taking prescription medications that may affect blood pressure, heart rate, or mental state
6. Not currently taking prescription stimulants or antidepressants

Healthy volunteers allowed
Yes

Age group
Adult

Lower age limit
18 Years

Upper age limit
50 Years

Sex
Male

Total final enrolment
12

Key exclusion criteria
1. Female sex
2. Age younger than 18 years or older than 50 years
3. Current tobacco smoking
4. Previously diagnosed or known chronic or cardiometabolic disease
5. Not meeting the American College of Sports Medicine guidelines for apparently healthy individuals
6. Current use of prescription medications that may influence blood pressure, heart rate, or mental state, including prescription stimulants or antidepressants

Date of first enrolment
03/03/2023

Date of final enrolment
15/03/2024

Locations

Countries of recruitment
United States of America

Sponsor information

Organisation
Baylor University

ROR
https://ror.org/005781934

Funder(s)

Funder type

Funder Name
Rucola Health

Funder Name
Baylor University

Alternative Name(s)
Baylor, BU

Funding Body Type
Government organisation

Funding Body Subtype
Universities (academic only)

Location
United States of America

Results and Publications

Individual participant data (IPD) sharing plan

IPD sharing plan summary
Not expected to be made available

Study outputs

Output type	Details	Date created	Date added	Peer reviewed?	Patient-facing?
Other files			05/11/2026	No	No
Protocol file			05/11/2026	No	No