*Training Report*

# Technical & Support Mission Report for Validation of Instrumental Textural Characterization of Fufu at NRCRI, Nigeria

## Biophysical Characterization of Quality Traits, WP2

**Umudike, Nigeria, December 2021**

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Ethics: The activities, which led to the production of this document, were assessed and approved by the CIRAD Ethics Committee (H2020 ethics self-assessment procedure). When relevant, samples were prepared according to good hygiene and manufacturing practices. When external participants were involved in an activity, they were priorly informed about the objective of the activity and explained that their participation was entirely voluntary, that they could stop the interview at any point and that their responses would be anonymous and securely stored by the research team for research purposes. Written consent (signature) was systematically sought from sensory panelists and from consumers participating in activities.

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| This document has been reviewed by: | |
|---|---|
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# ABSTRACT

The SOP validation, briefly, is aimed at confirmation of experimental outcomes of prior instrumental measurement of texture attributes of fufu, by testing the current generated data for agreement with prior measurements. Instrumental texture attributes such as hardness, adhesiveness, cohesiveness, springiness, gumminess, chewiness and resilience were measured using a texture analyser. A double compression mode was considered for the procedure as it simulates the action of the mastication of food.

Fermented cassava mash with contrasting cooking qualities obtained from three varieties of cassava were used to produce fufu. Two sets of replicate measurements were made for a fixed cylindrical sample geometry (40 mm x 47 mm) at 45 °C, and a combination of measurement parameters (pre-test speed 1mm/s, test speed 2 mm/s, strain 30%, compression cycle interlude 10 s, compression probe 100 mm diameter). Statistical analyses of the data obtained assist to determine the accuracy of data and validity of the procedure for texture measurement. Analysis of variance (ANOVA) to determine effect of measurement variables and repeatability between replicate measurements were conducted. Also, discrimination between various cassava genotypes based on their inherent textural attributes were viewed from principal components (PCA), discriminant, and hierarchical analyses.

Context: Validation of SOP on Instrumental Texture Profile Analysis of Fufu

Objectives: Evaluating repeatability between replicate measurements and discrimination between various cassava genotypes based on textural characteristics of Fufu

**Key Words: Textural attributes, PCA, Discriminant analysis, ANOVA, Fufu, Texture analyser, Hierarchical classification**

# 1 GENERAL OVERVIEW

## 1.1 Interest of this support mission in RTBfoods framework

- Validation of SOP on instrumental textural characterization of fufu
- Knowledge share & transfer of SOP among partners

## 1.2 Specific objectives

- Validation of SOP on instrumental textural characterization of fufu by testing protocol for accuracy, repeatability and discriminance.

## 1.3 Organizing committee

- Ugo CHIJIOKE, Food Technologist, National Roots Crop Research Institute (NRCRI)

## 1.4 Support team

| NAME First name | Gender (F/M) | External OR Position / Responsibilities within RTBfoods (ex: WP leader, Product Champion) | Background –Expertise (ex: Biochemistry) | Institute / Company + COUNTRY | Email Contact | Consent to Picture use (YES/NO) |
|---|---|---|---|---|---|---|
| AYETIGBO Oluwatoyin | M | Focal Point, Texture | Food Science & Physical measurements | CIRAD, France | Oluwatoyin.ayetigbo@cirad.fr | YES |

## 1.5 Targeted audience(s) & staff supported / trained

| # | NAME First name | Gender (F/M) | Position | Education - Background | Institute + COUNTRY | WP | Email Contact | Consent to Picture use (YES/NO) |
|---|---|---|---|---|---|---|---|---|
| 1 | CHIJIOKE Ugo | F | Food Scientist / Lead | Food Science | NRCRI Nigeria | 2 | ugochijioke4@gmail.com | YES |
| 2 | OKORONKWO Justice | M | Technical Official | Biochemistry | NRCRI Nigeria | 2 | justice_okoronkwo@yahoo.com | YES |
| 3 | ACHONWA Oluchi | F | Assistant | Food Science | NRCRI Nigeria | 2 | olyachonwa@gmail.com | YES |
| 4 | IRO Ugochi Jane | F | Assistant | - | NRCRI Nigeria | 2 | ugochijaneiro@gmail.com | YES |
| 5 | UDOKA Precious | F | Assistant | - | NRCRI Nigeria | 2 | preudoka@yahoo.com | YES |
| 6 | CHIKERE Juliet | F | Assistant | - | NRCRI Nigeria | 2 | - | YES |
| 7 | OGUNKA Amaka | F | Assistant | - | NRCRI Nigeria | 2 | Pinozichora268@gmail.com | YES |

## 1.6 Experience level of staff supported / trained

Ugo Chijioke is the lead Food Scientist at the Institute. She manages the lab, and has good knowledge on the texture measurement procedures.

Okoronkwo Justice is the primary technical officer focussed on the use of the texture analyser.

Oluchi Achonwa is the assistant to primary technical officer and focussed on assisting on the use of the texture analyser

Other assisting staff have varying skills such as in sample preparation prior to textural measurement.

# 2 SUPPORT IMPLEMENTATION

## 2.1 Support mission agenda

| **13 December** |
|---|
| • Arrival and familiarisation with staff, lab protocol and materials<br>• Test run of the texture analyser<br>• Conditioning of test materials (fermented cassava mash from 3 contrasting varieties of cassava)<br>• Discussion on prior experimental data (4 varieties, 2 replicates per variety, 5 measurements per replicate)<br>• Discussion with team and work plan breakdown<br>• Making sure of availability of all materials for start of measurements the following day |
| **14 December** |
| • Sample preparation of fufu from cooked mash following established SOP for fufu preparation<br>• Calibration and setting measurement parameters of texture analyser<br>• Measurements on texture analyser (2 varieties, 2 replicates per variety, 6 measurements per replicate) |
| **15 December** |
| • Sample preparation of fufu from cooked mash following established SOP for fufu preparation<br>• Calibration and setting measurement parameters of texture analyser<br>• Measurements on texture analyser (1 variety, 2 replicates per variety, 6 measurements per replicate)<br>• Data download and reposition<br>• Tentative discussion with team on results<br>• Preparation for analyses on next food product profile to be tested (boiled yam) |

## 2.2 Daily progress of the support mission

### DAY 1

**Who**: Ugo, Justice, Jane, Precious, Amaka

**Where**: Sample preparation room and Texture lab.

**What**:
- Introduction to staff member and assistants.
- Laboratory protocol, safety introduction.
- Review of staff competencies in texture measurements.
- Test running the texture analyser.
- Allocation of work duty to team members (fufu preparers, texture measuring staff, and other auxiliary functions for the smooth running of the work).

- 3 contrasting fermented fufu mash samples were conditioned at room temperature overnight.
- Draft of SOP shared.

**Specific Methods & Tools Used:**

Discussions

**Challenges Faced:**

- Problem with steady electricity. Therefore, the team manager planned fuelling and use of stand-by generator for the following day to prevent shutdown of the texture analyses system during activity.
- Institute was on strike and access was delayed into building.

**Output(s) – Result(s):**

Work plan agreed to avoid delays and electricity shutdown.

## DAY 2

**Who**: Ugo, Justice, Oluchi, Jane, Precious, Amaka

**Where**: Sample preparation room and Texture lab.

**What**:

- Texture SOP draft copy shared
- Texture analyser was calibrated with standard weight (2kg)
- Texture measurement parameters set (See SOP deliverables for details)
- Appropriate use of infrared thermometer
- Sample preparation was handled consistently by 2 assistants following fufu sample preparation SOP. Samples prepared in batch as consistently as possible.
- Only 2 contrasting varieties could be completed. Third variety will be concluded next day
- Measurements were taken. 2 replicates per variety, 6 measurements per replicate

**Specific Methods & Tools Used:**

- Fufu sample preparation SOP, Texture SOP draft
- Double compression using texture analyser

**Challenges Faced:**

A batch was discarded due to cooling down of sample prior to measurements

**Output(s) – Result(s):**

Texture measurements raw data

## DAY 3

**Who**: Ugo, Justice, Oluchi, Jane, Precious, Amaka

**Where**: Sample preparation room and Texture lab.

**What**:
- Texture analyser was calibrated with standard weight (2kg)
- Texture measurement parameters set
- Sample preparation was handled by same 2 assistants. Samples prepared in batch as consistently as possible.
- Only 1 contrasting variety was measured
- Data was collated and shared
- Tentative discussion with team on results
- Preparation for analyses on next food product profile to be tested (boiled yam) and collection of test yam materials

**Specific Methods & Tools Used:**

- Fufu sample preparation SOP, Texture SOP draft
- Double compression using texture analyser

**Challenges Faced:**

none

**Output(s) – Result(s):**

Texture measurements raw data

## 2.3 List of material / documents distributed

- Validated SOP on sample preparation for fufu
- Draft SOP on texture measurement of fufu

## 2.4 General approach - methods applied

- Open discussion with lab manager, technical officer and at least 3 assistants.
- Hands-on activities

# 3 MISSION OUTPUTS & FEEDBACKS

## 3.1 Specific outputs of the support mission

- Statistically accurate textural attribute data were generated (see Appendix 1)
- ANOVA and repeatability of textural data was confirmed (see Appendix 1)
- The three selected varieties were well discriminated based on textural attributes (see Appendix 1)
- Number of measurements per replicate confirmed to be sufficient for discrimination
- The most discriminant attributes were identified among attributes list
- Agreement of validation exercise outcomes with prior data (see Appendix 2)

## 3.2 Challenges faced – paths for improvement

- It was suggested that a dedicated stable power source should be provided solely for the texture analyser to overcome occasional power outage faced at initial stage of the exercise
- Most of support staff are not skilled sufficiently in statistical analyses. A training recommended.

## 3.3 Feedbacks from staff trained - general remarks from support team

- Request for statistical training in cleaning textural data and statistical analyses

## 3.4 Next steps

- Texture Profile analyses of a wider range of fufu samples from 11 cassava varieties
- Sensory analyses and correlation with textural data

***List of documents attached to the report***

| | |
|---|---|
| 1. SOP drafts for sample preparation and texture measurement | **Yes** |
| 2. Pictures | **No** |

# 4 APPENDICES

## 4.1 Annex 1: Statistical accuracy, ANOVA, repeatability and discriminance of texture of fufu at validation exercise

**Varieties:**

- 0505 – preferred elite variety
- 1368 – least preferred elite clone
- Wonono – Intermediate local variety

**Statistical accuracy of texture attributes measured**

| | variety | cooking replicate | N | Mean | Std Err | CV |
|---|---|---|---|---|---|---|
| Hardness (g) | 505 | 1 | 6 | 653.87 | 15.60 | 5.8 |
| | | 2 | 6 | 812.91 | 43.13 | 13.0 |
| | 1368 | 1 | 7 | 1864.95 | 60.76 | 8.6 |
| | | 2 | 6 | 1803.14 | 42.82 | 5.8 |
| | wonono | 1 | 7 | 668.58 | 15.86 | 6.3 |
| | | 2 | 6 | 611.92 | 24.82 | 9.9 |
| Adhesiveness (g·s) | 505 | 1 | 6 | -206.34 | 26.67 | -31.7 |
| | | 2 | 6 | -145.56 | 21.86 | -36.8 |
| | 1368 | 1 | 7 | -283.70 | 106.20 | -99.0 |
| | | 2 | 6 | -685.18 | 282.59 | -101.0 |
| | wonono | 1 | 7 | -43.28 | 8.08 | -49.4 |
| | | 2 | 6 | -81.25 | 4.66 | -14.0 |
| Springiness (%) | 505 | 1 | 6 | 0.326 | 0.014 | 10.2 |
| | | 2 | 6 | 0.282 | 0.013 | 11.7 |
| | 1368 | 1 | 7 | 0.343 | 0.008 | 6.0 |
| | | 2 | 6 | 0.326 | 0.007 | 5.3 |
| | wonono | 1 | 7 | 0.231 | 0.012 | 13.6 |
| | | 2 | 6 | 0.259 | 0.006 | 5.5 |
| Cohesiveness (-) | 505 | 1 | 6 | 0.335 | 0.006 | 4.1 |
| | | 2 | 6 | 0.315 | 0.015 | 11.5 |
| | 1368 | 1 | 7 | 0.353 | 0.011 | 8.0 |
| | | 2 | 6 | 0.330 | 0.008 | 5.9 |
| | wonono | 1 | 7 | 0.259 | 0.012 | 11.9 |
| | | 2 | 6 | 0.290 | 0.003 | 2.3 |
| Gumminess (g) | 505 | 1 | 6 | 218.73 | 6.03 | 6.8 |
| | | 2 | 6 | 253.46 | 8.15 | 7.9 |
| | 1368 | 1 | 7 | 660.13 | 32.82 | 13.2 |
| | | 2 | 6 | 595.12 | 20.23 | 8.3 |
| | wonono | 1 | 7 | 173.79 | 10.95 | 16.7 |
| | | 2 | 6 | 177.64 | 8.16 | 11.2 |
| Chewiness(g) | 505 | 1 | 6 | 71.63 | 4.46 | 15.3 |
| | | 2 | 6 | 71.55 | 4.53 | 15.5 |
| | 1368 | 1 | 7 | 227.13 | 14.96 | 17.4 |
| | | 2 | 6 | 194.51 | 9.59 | 12.1 |
| | wonono | 1 | 7 | 40.75 | 4.34 | 28.2 |
| | | 2 | 6 | 46.13 | 2.58 | 13.7 |
| Resilience (-) | 505 | 1 | 6 | 0.072 | 0.003 | 11.4 |
| | | 2 | 6 | 0.077 | 0.002 | 5.3 |
| | 1368 | 1 | 7 | 0.111 | 0.005 | 11.3 |
| | | 2 | 6 | 0.095 | 0.003 | 8.3 |
| | wonono | 1 | 7 | 0.084 | 0.004 | 12.2 |
| | | 2 | 6 | 0.081 | 0.003 | 8.1 |

Outliers were not cleaned from data. Outliers can be cleaned by statistical analysis

**ANOVA and Repeatability of textural parameters**

Hardness

**By Variety**

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| variety | 2 | 11368967 | 5684484 | 496.3815 | <.0001* |
| Error | 35 | 400815 | 11452 | | |
| C. Total | 37 | 11769782 | | | |

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 0505 | 12 | 733.38842 | 112.40503 | 32.448537 | 661.96967 | 804.80716 |
| 1368 | 13 | 1836.4202 | 136.14056 | 37.758599 | 1754.1512 | 1918.6891 |
| wonono | 13 | 642.43077 | 57.314711 | 15.896241 | 607.79584 | 677.0657 |

**Connecting Letters Report**

| Level | | Mean |
|---|---|---|
| 1368 | A | 1836.4202 |
| 0505 | B | 733.3884 |
| wonono | B | 642.4308 |

Levels not connected by same letter are significantly different.

**Ordered Differences Report**

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| 1368 | wonono | 1193.989 | 41.97407 | 1091.27 | 1296.711 | <.0001* |
| 1368 | 0505 | 1103.032 | 42.83960 | 998.19 | 1207.872 | <.0001* |
| 0505 | wonono | 90.958 | 42.83960 | -13.88 | 195.798 | 0.0997 |

**By cooking replicate**

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| cooking replicate | 1 | 452 | 452 | 0.0014 | 0.9705 |
| Error | 36 | 11769330 | 326926 | | |
| C. Total | 37 | 11769782 | | | |

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 1 | 20 | 1082.8966 | 596.48758 | 133.37868 | 803.73177 | 1362.0613 |
| 2 | 18 | 1075.9884 | 542.82369 | 127.94477 | 806.04857 | 1345.9283 |

**Connecting Letters Report**

| Level | | Mean |
|---|---|---|
| 1 | A | 1082.8966 |
| 2 | A | 1075.9884 |

Levels not connected by same letter are significantly different.

**Ordered Differences Report**

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| 1 | 2 | 6.908106 | 185.7655 | -369.845 | 383.6615 | 0.9705 |

Adhesiveness

**By Variety**

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| variety | 2 | 1148009.6 | 574005 | 5.8317 | 0.0065* |
| Error | 35 | 3444973.3 | 98428 | | |
| C. Total | 37 | 4592982.9 | | | |

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 0505 | 12 | -175.9489 | 65.200111 | 18.821651 | -217.3751 | -134.5227 |
| 1368 | 13 | -468.9994 | 531.51965 | 147.41703 | -790.1935 | -147.8053 |
| wonono | 13 | -60.80608 | 25.906976 | 7.1853024 | -76.46151 | -45.15065 |

**Connecting Letters Report**

| Level | | | Mean |
|---|---|---|---|
| wonono | A | | -60.8061 |
| 0505 | A | B | -175.9489 |
| 1368 | | B | -468.9994 |

Levels not connected by same letter are significantly different.

**By cooking replicate**

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| cooking replicate | 1 | 154375.1 | 154375 | 1.2521 | 0.2706 |
| Error | 36 | 4438607.8 | 123295 | | |
| C. Total | 37 | 4592982.9 | | | |

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 1 | 20 | -176.3451 | 193.00735 | 43.157756 | -266.6753 | -86.01488 |
| 2 | 18 | -303.9976 | 468.46576 | 110.41844 | -536.9601 | -71.03501 |

**Connecting Letters Report**

| Level | | Mean |
|---|---|---|
| 1 | A | -176.3451 |
| 2 | A | -303.9976 |

Levels not connected by same letter are significantly different.

| By Variety | By cooking replicate |
|---|---|

**Ordered Differences Report**

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| wonono | 1368 | 408.1933 | 123.0558 | 107.042 | 709.3449 | 0.0059* |
| 0505 | 1368 | 293.0505 | 125.5933 | -14.311 | 600.4120 | 0.0642 |
| wonono | 0505 | 115.1428 | 125.5933 | -192.219 | 422.5044 | 0.6335 |

**Ordered Differences Report**

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| 1 | 2 | 127.6525 | 114.0808 | -103.716 | 359.0212 | 0.2706 |

Springiness

| By Variety | By cooking replicate |
|---|---|

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| variety | 2 | 0.05565297 | 0.027826 | 31.1448 | <.0001* |
| Error | 35 | 0.03127092 | 0.000893 | | |
| C. Total | 37 | 0.08692389 | | | |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| cooking replicate | 1 | 0.00087309 | 0.000873 | 0.3653 | 0.5494 |
| Error | 36 | 0.08605080 | 0.002390 | | |
| C. Total | 37 | 0.08692389 | | | |

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 0505 | 12 | 0.304 | 0.0391756 | 0.011309 | 0.279109 | 0.328891 |
| 1368 | 13 | 0.335 | 0.0202155 | 0.0056068 | 0.3227839 | 0.3472161 |
| wonono | 13 | 0.2439231 | 0.0281142 | 0.0077975 | 0.2269338 | 0.2609123 |

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 1 | 20 | 0.2986 | 0.0581354 | 0.0129995 | 0.2713918 | 0.3258082 |
| 2 | 18 | 0.289 | 0.0358395 | 0.0084475 | 0.2711774 | 0.3068226 |

**Connecting Letters Report**

| Level | | Mean |
|---|---|---|
| 1368 | A | 0.33500000 |
| 0505 | B | 0.30400000 |
| wonono | C | 0.24392308 |

Levels not connected by same letter are significantly different.

**Connecting Letters Report**

| Level | | Mean |
|---|---|---|
| 1 | A | 0.29860000 |
| 2 | A | 0.28900000 |

Levels not connected by same letter are significantly different.

**Ordered Differences Report**

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| 1368 | wonono | 0.0910769 | 0.0117241 | 0.0623848 | 0.1197690 | <.0001* |
| 0505 | wonono | 0.0600769 | 0.0119659 | 0.0307932 | 0.0893607 | <.0001* |
| 1368 | 0505 | 0.0310000 | 0.0119659 | 0.0017162 | 0.0602838 | 0.0361* |

**Ordered Differences Report**

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| 1 | 2 | 0.0096000 | 0.0158843 | -0.022615 | 0.0418150 | 0.5494 |

Cohesiveness

| By Variety | By cooking replicate |
|---|---|

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| variety | 2 | 0.03328369 | 0.016642 | 22.4386 | <.0001* |
| Error | 35 | 0.02595813 | 0.000742 | | |
| C. Total | 37 | 0.05924182 | | | |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| cooking replicate | 1 | 0.00008400 | 0.000084 | 0.0511 | 0.8224 |
| Error | 36 | 0.05915781 | 0.001643 | | |
| C. Total | 37 | 0.05924182 | | | |

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 0505 | 12 | 0.3248333 | 0.0280481 | 0.0080968 | 0.3070124 | 0.3426543 |
| 1368 | 13 | 0.3424615 | 0.0263964 | 0.007321 | 0.3265104 | 0.3584127 |
| wonono | 13 | 0.2734615 | 0.0272996 | 0.0075716 | 0.2569645 | 0.2899585 |

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 1 | 20 | 0.3147 | 0.0489759 | 0.0109514 | 0.2917786 | 0.3376214 |
| 2 | 18 | 0.3117222 | 0.0282672 | 0.0066626 | 0.2976653 | 0.3257792 |

## By Variety

**Connecting Letters Report**

| Level | | Mean |
|---|---|---|
| 1368 | A | 0.34246154 |
| 0505 | A | 0.32483333 |
| wonono | B | 0.27346154 |

Levels not connected by same letter are significantly different.

**Ordered Differences Report**

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| 1368 | wonono | 0.0690000 | 0.0106818 | 0.042859 | 0.0951414 | <.0001* |
| 0505 | wonono | 0.0513718 | 0.0109021 | 0.024691 | 0.0780523 | 0.0001* |
| 1368 | 0505 | 0.0176282 | 0.0109021 | -0.009052 | 0.0443087 | 0.2520 |

## By cooking replicate

**Connecting Letters Report**

| Level | | Mean |
|---|---|---|
| 1 | A | 0.31470000 |
| 2 | A | 0.31172222 |

Levels not connected by same letter are significantly different.

**Ordered Differences Report**

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| 1 | 2 | 0.0029778 | 0.0131703 | -0.023733 | 0.0296886 | 0.8224 |

Gumminess

## By Variety

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| variety | 2 | 1571335.2 | 785668 | 323.7345 | <.0001* |
| Error | 35 | 84941.1 | 2427 | | |
| C. Total | 37 | 16562763 | | | |

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 0505 | 12 | 236.09792 | 24.680916 | 7.1247667 | 220.41641 | 251.77942 |
| 1368 | 13 | 630.12669 | 77.008138 | 21.358215 | 583.59114 | 676.66224 |
| wonono | 13 | 175.57131 | 24.28553 | 6.7355943 | 160.89571 | 190.24691 |

**Connecting Letters Report**

| Level | | Mean |
|---|---|---|
| 1368 | A | 630.12669 |
| 0505 | B | 236.09792 |
| wonono | C | 175.57131 |

Levels not connected by same letter are significantly different.

**Ordered Differences Report**

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| 1368 | wonono | 454.5554 | 19.32272 | 407.2674 | 501.8434 | <.0001* |
| 1368 | 0505 | 394.0288 | 19.72117 | 345.7656 | 442.2919 | <.0001* |
| 0505 | wonono | 60.5266 | 19.72117 | 12.2635 | 108.7897 | 0.0112* |

## By cooking replicate

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| cooking replicate | 1 | 2252.2 | 2252.2 | 0.0490 | 0.8260 |
| Error | 36 | 1654024.0 | 45945.1 | | |
| C. Total | 37 | 16562763 | | | |

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 1 | 20 | 357.49435 | 234.43482 | 52.421219 | 247.77548 | 467.21322 |
| 2 | 18 | 342.07567 | 189.39378 | 44.640541 | 247.89236 | 436.25898 |

**Connecting Letters Report**

| Level | | Mean |
|---|---|---|
| 1 | A | 357.49435 |
| 2 | A | 342.07567 |

Levels not connected by same letter are significantly different.

**Ordered Differences Report**

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| 1 | 2 | 15.41868 | 69.64023 | -125.820 | 156.6569 | 0.8260 |

Chewiness

## By Variety

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| variety | 2 | 211113.96 | 105557 | 206.5014 | <.0001* |
| Error | 35 | 17890.89 | 511 | | |
| C. Total | 37 | 229004.85 | | | |

## By cooking replicate

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| cooking replicate | 1 | 1184.51 | 1184.51 | 0.1872 | 0.6679 |
| Error | 36 | 22782035 | 6328.34 | | |
| C. Total | 37 | 229004.85 | | | |

| By Variety | By cooking replicate |
|---|---|

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 0505 | 12 | 71.592167 | 10.499353 | 3.030902 | 64.921196 | 78.263137 |
| 1368 | 13 | 212.07715 | 36.045631 | 9.9972593 | 190.295 | 233.85931 |
| wonono | 13 | 43.230923 | 9.5168334 | 2.6394947 | 37.479958 | 48.981888 |

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 1 | 20 | 115.2469 | 88.460598 | 19.780391 | 73.846066 | 156.64773 |
| 2 | 18 | 104.06517 | 68.229749 | 16.081906 | 70.135311 | 137.99502 |

**Connecting Letters Report**

| Level | | Mean |
|---|---|---|
| 1368 | A | 212.07715 |
| 0505 | B | 71.59217 |
| wonono | C | 43.23092 |

Levels not connected by same letter are significantly different.

**Connecting Letters Report**

| Level | | Mean |
|---|---|---|
| 1 | A | 115.24690 |
| 2 | A | 104.06517 |

Levels not connected by same letter are significantly different.

**Ordered Differences Report**

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| 1368 | wonono | 168.8462 | 8.867992 | 147.1438 | 190.5487 | <.0001* |
| 1368 | 0505 | 140.4850 | 9.050857 | 118.3350 | 162.6349 | <.0001* |
| 0505 | wonono | 28.3612 | 9.050857 | 6.2113 | 50.5112 | 0.0095* |

**Ordered Differences Report**

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| 1 | 2 | 11.18173 | 25.84554 | -41.2359 | 63.59938 | 0.6679 |

Resilience

| By Variety | By cooking replicate |
|---|---|

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| variety | 2 | 0.00584341 | 0.002922 | 29.2815 | <.0001* |
| Error | 35 | 0.00349230 | 0.000100 | | |
| C. Total | 37 | 0.00933571 | | | |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| cooking replicate | 1 | 0.00032298 | 0.000323 | 1.2901 | 0.2635 |
| Error | 36 | 0.00901273 | 0.000250 | | |
| C. Total | 37 | 0.00933571 | | | |

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 0505 | 12 | 0.0745833 | 0.0066258 | 0.0019127 | 0.0703735 | 0.0787932 |
| 1368 | 13 | 0.1038462 | 0.0133532 | 0.0037035 | 0.0957769 | 0.1119154 |
| wonono | 13 | 0.0821538 | 0.0085132 | 0.0023611 | 0.0770094 | 0.0872983 |

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 1 | 20 | 0.08995 | 0.0195972 | 0.0043821 | 0.0807782 | 0.0991218 |
| 2 | 18 | 0.0841111 | 0.0100463 | 0.0023679 | 0.0791152 | 0.089107 |

**Connecting Letters Report**

| Level | | Mean |
|---|---|---|
| 1368 | A | 0.10384615 |
| wonono | B | 0.08215385 |
| 0505 | B | 0.07458333 |

Levels not connected by same letter are significantly different.

**Connecting Letters Report**

| Level | | Mean |
|---|---|---|
| 1 | A | 0.08995000 |
| 2 | A | 0.08411111 |

Levels not connected by same letter are significantly different.

**Ordered Differences Report**

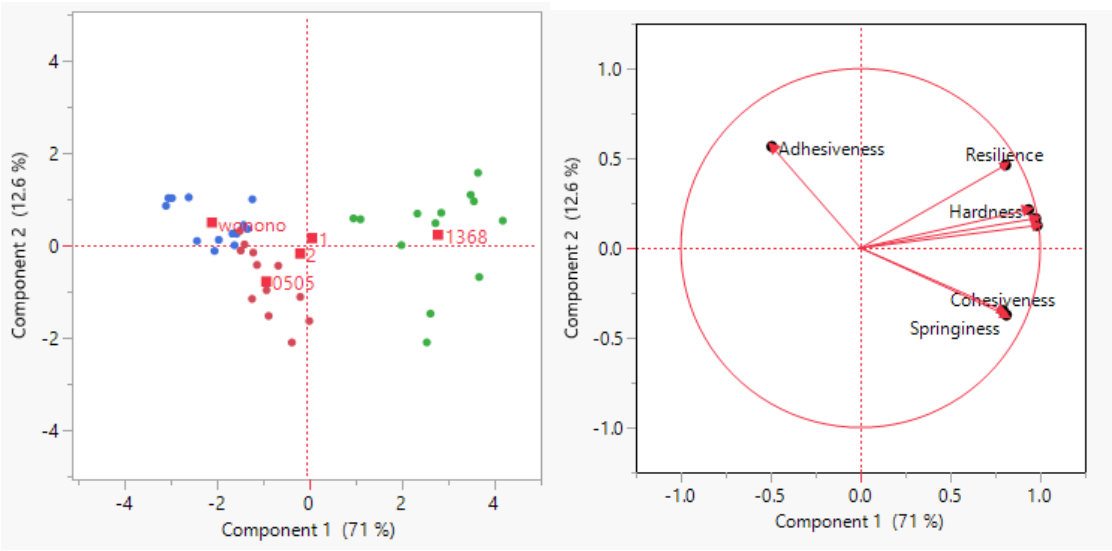
| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| 1368 | 0505 | 0.0292628 | 0.0039988 | 0.019477 | 0.0390490 | <.0001* |
| 1368 | wonono | 0.0216923 | 0.0039180 | 0.012104 | 0.0312807 | <.0001* |
| wonono | 0505 | 0.0075705 | 0.0039988 | -0.002216 | 0.0173567 | 0.1557 |

**Ordered Differences Report**

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| 1 | 2 | 0.0058389 | 0.0051406 | -0.004587 | 0.0162647 | 0.2635 |

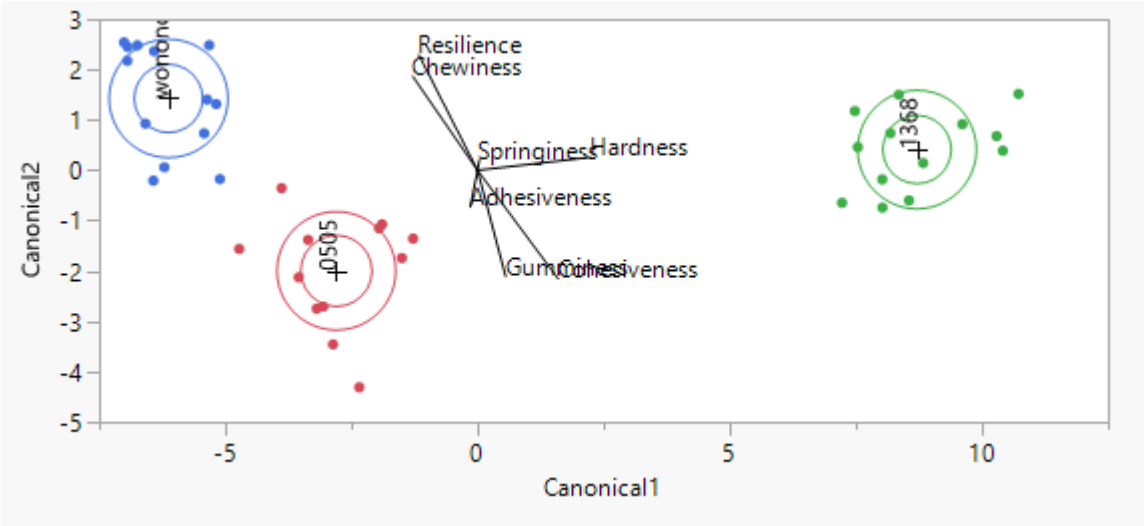
The TPA parameters for the varieties generally showed good repeatability and no significant differences between the cooking replicate means.

**Discriminance between varieties based on textural profile**



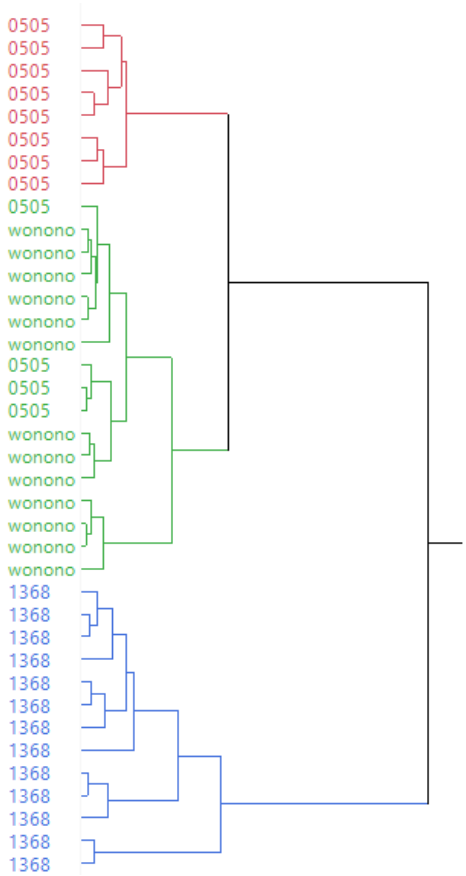

**PCA**

The first two components of the PCA explained 83.6 % of the variation. The PCA & discriminance analyses show that the varieties were grouped into separate components, thereby showing discriminance between the textural parameters of the varieties.




**Discriminance**

Discriminance analysis shows hardness is particularly positively associated with the canonical space, and therefore carry more weight in discriminating between varieties. Adhesiveness and springiness were not significant in discriminating the varieties. The more discriminating textural attributes are, therefore, cohesiveness, hardness, resilience, chewiness and gumminess.




**Hierarchical classes**

The varieties were clustered in three groups but with some interloping between wonono and 0505.

**Summary**

All TPA parameters for all the varieties generally showed good repeatability with no significant differences between the replicate means. Discriminance was good between the varieties based on ITPA.

This outcome validates previous experiment on TPA of fufu, where similar results were obtained.

**Conclusion**

TPA may be conducted with a texture analyser in determining discriminant character of textural attributes of fufu made from various cassava genotypes. A minimum of 6 measurements per replicate and 2 replicates per variety was sufficient to discriminate between the varieties.

## 4.2 Annex 2: Excerpts from prior experiments - repeatability and discriminance of texture of fufu

**Varieties:**

- 518 – preferred elite variety
- 1368 – least preferred elite clone
- Chenke – preferred local variety
- Wonono – Intermediate local variety

## Example of ANOVA and Repeatability of Hardness attribute

### By Variety

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| variety | 3 | 10691974 | 3563991 | 333.9863 | <.0001* |
| Error | 36 | 384159 | 10671 | | |
| C. Total | 39 | 11076132 | | | |

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 0518 | 10 | 631.9367 | 51.066934 | 16.148782 | 595.40562 | 668.46778 |
| 1368 | 10 | 1990.2995 | 190.58114 | 60.267048 | 1853.966 | 2126.633 |
| chenke | 10 | 857.2491 | 39.369432 | 12.449707 | 829.08591 | 885.41229 |
| wonono | 10 | 1048.5256 | 46.960885 | 14.850336 | 1014.9318 | 1082.1194 |

**Connecting Letters Report**

| Level | | Mean |
|---|---|---|
| 1368 | A | 1990.2995 |
| wonono | B | 1048.5256 |
| chenke | C | 857.2491 |
| 0518 | D | 631.9367 |

Levels not connected by same letter are significantly different.

**Ordered Differences Report**

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| 1368 | 0518 | 1358.363 | 46.19755 | 1233.942 | 1482.783 | <.0001* |
| 1368 | chenke | 1133.050 | 46.19755 | 1008.630 | 1257.471 | <.0001* |
| 1368 | wonono | 941.774 | 46.19755 | 817.353 | 1066.194 | <.0001* |
| wonono | 0518 | 416.589 | 46.19755 | 292.168 | 541.009 | <.0001* |
| chenke | 0518 | 225.312 | 46.19755 | 100.892 | 349.733 | 0.0001* |
| wonono | chenke | 191.277 | 46.19755 | 66.856 | 315.697 | 0.0011* |

### By cooking replicate

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| cooking replicate | 1 | 20050 | 20050 | 0.0689 | 0.7943 |
| Error | 38 | 11056082 | 290950 | | |
| C. Total | 39 | 11076132 | | | |

**Means and Std Deviations**

| Level | Number | Mean | Std Dev | Std Err Mean | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| 1 | 20 | 1154.3914 | 589.9035 | 131.90643 | 878.30806 | 1430.4747 |
| 2 | 20 | 1109.6141 | 483.64544 | 108.14641 | 883.26101 | 1335.9671 |

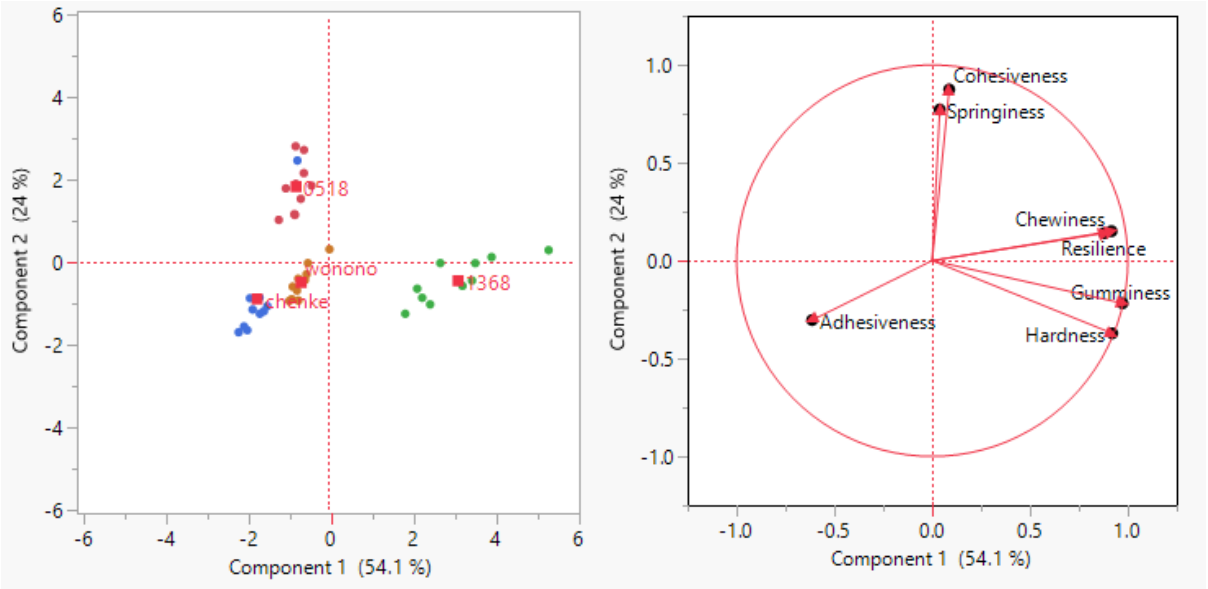
**Connecting Letters Report**

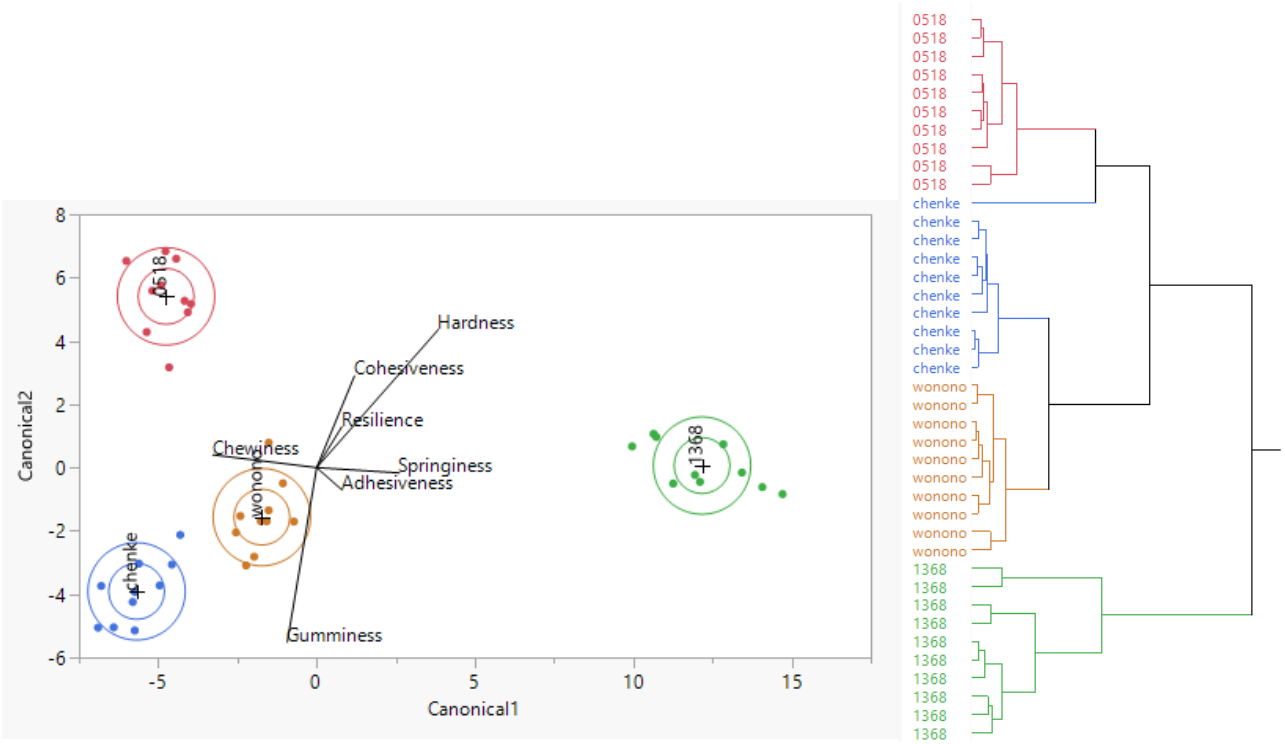
| Level | | Mean |
|---|---|---|
| 1 | A | 1154.3914 |
| 2 | A | 1109.6141 |

Levels not connected by same letter are significantly different.

**Ordered Differences Report**

| Level | - Level | Difference | Std Err Dif | Lower CL | Upper CL | p-Value |
|---|---|---|---|---|---|---|
| 1 | 2 | 44.77735 | 170.5724 | -300.532 | 390.0868 | 0.7943 |






PCA, discriminant and hierarchical analyses of fufu texture from 4 contrasting cassava varieties

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