Effect of thermosonication on quality attributes of hog plum (Spondias mombin L.) juice

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ABSTRACT

The use of thermosonication (TS) technique to preserve the qualities of fruit juice as an alternative to conventional pasteurization has attracted research interest in recent times. In the present study, freshly prepared hog plum juice (control), and the juice samples subjected to pasteurization (90 °C for 60 s) and thermosonication (40 kHz, 400 W at 40, 50 and 60 °C each for 5, 10, 20 and 30 min) were each analyzed for physicochemical, bioactive, microbial and sensory properties. After treatment, no significant changes in pH, total soluble solids and titratable acidity were observed. Notably, TS at 40 and 50 °C significantly (p < 0.05) improved color parameters, cloudiness and browning index. Furthermore, thermosonication increased ascorbic acid (11.40–18.55%), total phenolic content (17.98–18.35%), carotenoids (2.19–4.30%), flavonoids (10–16%) and antioxidant activity (32.52–48.5%) relative to the control. Both treatments significantly reduced the microbial count to non-detectable level after processing, while sensory attributes slightly improved. However, TS treatment at 60 °C decreased most of the quality parameters. Results showed that TS can improve quality, safety and economic potential of hog plum juice as a feasible alternative to pasteurization.

1. Introduction

Fruit juices constitute an integral component of the human diet. They are regarded as excellent sources of micronutrients such as vitamins, minerals and some phytochemicals which offer nutritional and health benefits [1,2]. Meanwhile, fruit juices are often subject to quality deterioration due to poor processing and storage conditions, thus constituting quality and safety challenges [3]. Traditionally, pasteurization (at < 100 °C for few seconds/minutes to achieve a 5-log reduction) has been applied to attain microbial safety and quality preservation of fruit juices [4,5].

Hog plum (Spondias mombin L.) also known as “yellow mombin” is a wild, but exotic fruit from a small deciduous tree belonging to the Anacardiaceae family [6]. The fruit which is indigenous to tropical areas of America, Asia and Africa has a unique blend of sweet-sour taste and is recently gaining research attention in Nigeria [7]. Nutritionally, hog plum juice is a rich source of vitamins A and C, minerals such as potassium and phosphorus, and certain health-promoting phytochemicals [8,9]. Pasteurization of this juice for quality retention has been investigated, but the authors reported some quality losses and deleterious alterations [10]. As a result of this development, the need for novel and alternative processing method to meet consumers’ demand becomes imminent. The potential use of ultrasound technology has gained veritable attention in recent times to meet the requirements of the U.S. Food and Drug Administration (FDA) in the beverage industry [11]. Furthermore, the combination of controlled temperature (thermo) with ultrasound (sonication) called thermosonication (TS) has been reported to improve quality and safety characteristics of fruit juice [12–14]. This technique which operates at a frequency of 20–100 kHz causes cavitation in cellular structures, leading to membrane disruption, pore formation and eventual breakage or fragmentation [15–17]. Thermosonication treatment has reportedly achieved significant improvement in the color, bioactive compounds and microbial safety of several fruit juices such as mango [18], pineapple [19], star fruit [20], apple [21], soursop [22], pitaya [23] and black mulberry [24]. Hence, preserving the quality of juice from this exotic but seasonal fruit using TS will be another way to enhance its nutritional and economic value to its various consumers. To the best of authors’ knowledge, there has been a paucity of information on thermosonicated hog plum juice. Therefore, the objective of this study was to investigate the quality attributes of juice from hog plum using thermosonication technique.

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2. Materials and method

2.1. Fruit preparation.

Matured and ripe hog plum fruits (Spondias mombin L.) were harvested from the University of Ibadan's horticultural garden into plastic crates and brought to the Food Technology research laboratory. The fruits were properly rinsed with distilled water (pH 7.0 ± 0.2) while defective ones were removed. Rinsed fruits were air-dried at room temperature for 5 min in a Class II biosafety cabinet (BSC-15001 B2-X Labotech, Midrand 1685, South Africa) before juice extraction. All chemicals used in the present study were of analytical grade from Sigma Aldrich (Buchs Switzerland).

2.2. Juice extraction and treatment procedure

The fruit peels were carefully removed and pulp scraped from the seed using a sterilized stainless steel knife. The pulp was thereafter fed into a motorized juice extractor (Model: TMG 4100025; Mumbai, India) for about 10 sec to obtain the juice. The juice was filtered with a sterile muslin cloth for homogenous consistency. Extracted juice was treated as raw (RJ), pasteurized (PJ) and thermosonicated (TS).

2.3. Pasteurization and thermosonication treatment

In the pasteurized sample, hog plum juice was pasteurized in a laboratory-scale pasteurizer (JBN 26. Grant Inst., Ltd. Cambridge SG86GGB, UK) at 90 °C for 60 s to achieve a 5 log microbial reduction following a modified method of Santhirasegaram, Razali [25]. The juice sample was thereafter cooled in an ice bath and stored under refrigerated condition (4 °C) before analysis. Thermosonication treatment of hog plum juice sample was carried out according to a modified method reported by Aadil, Zeng [11] in a digital ultrasonic bath (Grant Inst. XUB 25 Cambridge, UK) at a frequency of 40 kHz. The digital ultrasonic bath (with a maximum tank capacity of 28 L) has a rectangular dimension of 365 × 385 × 546 mm. The 40 kHz transducer underneath transmits 400 W ultrasonic wave power into the bath vessel at acoustic energy density (AED) of 0.348 W/cm3. Hog plum juice sample in 500 ml beaker was placed carefully in the middle of the ultrasonic bath at the same water level in the bath. This process was varied at 40, 50 and 60 °C each for 5, 10, 20 and 30 min at the stated frequency, power and AED (Table 1). All the treatments were done in the dark during sonication to avoid any possible interference of light. After processing, juice samples were cooled in an ice bath, poured carefully into plastic bottles and kept under refrigerated storage (4 °C) before further analysis.

Table 1

| Treatment | Temperature (°C) | Time (min) | AED (W/cm3) | Ultrasonic power (W) | Frequency (kHz) |
|-----------|----------------|------------|-------------|---------------------|-----------------|
| Raw juice | –              | –          | –           | –                   | –              |
| Pasteurized juice | 90 | 1 | 0.348 | 400 | 40 |
| TS-R     | 40           | 5          | 0.348       | 400                 | 40              |
| TS-T     | 40           | 10         | 0.348       | 400                 | 40              |
| TS-S     | 40           | 20         | 0.348       | 400                 | 40              |
| TS-D     | 40           | 30         | 0.348       | 400                 | 40              |
| TS-I     | 50           | 5          | 0.348       | 400                 | 40              |
| TS-E     | 50           | 10         | 0.348       | 400                 | 40              |
| TS-F     | 50           | 20         | 0.348       | 400                 | 40              |
| TS-H     | 50           | 30         | 0.348       | 400                 | 40              |
| TS-G     | 60           | 5          | 0.348       | 400                 | 40              |
| TS-J     | 60           | 10         | 0.348       | 400                 | 40              |
| TS-I     | 60           | 20         | 0.348       | 400                 | 40              |
| TS-H     | 60           | 30         | 0.348       | 400                 | 40              |

*AED: Acoustic energy density, TS: Thermosonicated samples

2.4. Physicochemical analysis-pH, TSS, TA and color parameters

The pH values of raw and treated juices were obtained using pH meter (Model Basic 2; Crison Instrument, Barcelona, Spain) at 20 °C. Total soluble solids (TSS, ° Brix) was determined by measurement of refractive index at 25 ± 1 °C using a digital refractometer (Atago Co. Ltd., Tokyo, Japan). Titratable acidity (TA) was determined by diluting 10 ml of each juice sample with 10 ml of distilled water in a 100 ml volumetric flask. Diluted samples were titrated against 0.1 N NaOH up to 8.1 pH value using phenolphthalein as an indicator. The titration was done in triplicate and calculated as percentage citric acid.

Color parameters L* (lightness), a* (redness to greenness), b* (yellowness to blueness) of the juice was measured using a colorimeter (Chroma meter CR-400, Konika Minolta, USA). The color intensity was calculated using the formula

\[
\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}.
\]

All determinations were carried out three times per treatment.

2.5. Cloudiness and browning indices

Cloudiness and browning indices were determined following a modified method reported by Cervantes-Elizarrarás, Piloni-Martini [26]. About 5 ml of hog plum juice was centrifuged (5810R; Eppendorf Hamburg, Germany) at 3500 × g for 20 min. The supernatant obtained was used for calculation of both indices. For cloudiness index, absorbance value was obtained at 660 nm using a spectrophotometer (T70 UV–VIS spectrophotometer, PG instruments, Alma Park, UK), while for the browning index, 5 ml of the supernatant together with ethanol was centrifuged at 3500 × g for 20 min and the absorbance value of supernatant obtained again was read at 420 nm in the spectrophotometer.

2.6. Ascorbic acid content

The ascorbic acid (AA) content was determined according to a method of Rahman, Khan [27] with slight modification. The method is based on the oxidizing strength of bromine water on ascorbic acid to dehydroascorbic acid using acetic acid. Here, the mixture containing hog plum juice was treated with 1 ml of 2, 4-dinitrophenyl hydrazine at 37 °C for 3 h, and the resulting solution was further treated with H2SO4 acid (1.0 mol dm–3) to produce red color complex. Absorbance was measured at 521 nm using a spectrophotometer (T70 UV–VIS spectrophotometer, PG instruments, Alma Park, UK). AA content was calculated and expressed as milligram per 100 ml of juice (mg/100 ml) using a calibration curve of standard ascorbic acid.

2.7. Determination of total phenolic, total carotenoid, total flavonoid and antioxidant capacity.

Total phenolic content (TPC) was determined using the Folin-Ciocalteu assay method reported by Matkowski and Piotrowska [28]. Absorbance was measured at 760 nm using a spectrophotometer (T70 UV–VIS spectrophotometer, PG instruments, Alma Park, UK). Total phenol content was expressed as mg/g of juice extract using Gallic acid standard curve.

Total carotenoid (TC) determination was carried out following the modified method of Lee and Castle [29]. Juice sample (2 ml) was added to 50 ml of water-saturated n-butanol and mixed thoroughly by hand-shaking. The mixture was kept in the dark for 16–18 h for proper extraction of carotenoid and centrifuged (5810R; Eppendorf Hamburg, Germany) at 10,000 × g for 10 min. The supernatant of the solvent containing the carotenoid was recovered and the absorbance measured at 440 nm on a spectrophotometer (T70 UV–VIS spectrophotometer, PG
Antioxidant activity (%) \( (\frac{A_A}{A}) \times 100 \) was calculated using the formula recorded at 517 nm after 1 h. Inhibition of free radical by DPPH was added to 4 ml of a methanol solution of DPPH. Absorbance was recorded at 517 nm after 1 h. Inhibition of free radical by DPPH was calculated using the formula

\[
\text{Antioxidant activity}(\%) = \left( \frac{A_c - A_s}{A_c} \right) \times 100
\]

where: \( A_c \) – absorbance of the control mixture (containing all reagents except the test compound); \( A_s \) – absorbance of the prepared sample or standard

### 2.8. Microbial analysis

Microbial enumeration of total plate counts, yeasts, and mold counts was carried out according to the modified method of Nayak, Rayaguru [30]. Total plate count was evaluated using the plate count agar (PCA; Oxoid, Basingstoke, Hampshire, UK) and incubating at 37 °C for 48 h. The enumeration of yeast and mold was also done using potato dextrose agar (PDA; Oxoid, Basingstoke, Hampshire, UK) via spread plate technique. Adjustment of media was done to pH 3.5 during preparation using 100 g/L tartaric acid and incubated at 25 °C for 120 h. and colonies counted and expressed as log CFU/ml.

### 2.9. Sensory analysis

All sensory evaluation process was performed at the food laboratory, the University of Ibadan using an untrained panel consisting of 50 students (24 males and 26 females) with 26 years mean age who were familiar with the fruit. Panelists were instructed to rinse their mouth with tap water between sample evaluations. The juice samples were assessed for taste, color, flavour, mouth feel, and overall acceptability according to the hedonic scale of nine points (9 = like extremely to 1 = dislike extremely) as reported by Basu, Shivhare [32].

### 2.10. Statistical analysis

All experiments were performed in triplicates (n = 3). Data from each treatment were subjected to analysis of variance (ANOVA) using SPSS software (IBM 24 SPSS Inc., Chicago, Ill., USA) and means separated using Duncan multiple range tests (p < 0.05).

### 3. Results and discussion

#### 3.1. Physicochemical properties (pH, TSS, TA)

In the present study, the pH, TSS and TA of the raw juice was not significantly different from those of both pasteurized and thermosonicated (TSa-L) samples (Table 1). Hence the pH (2.32–2.36), TSS (5.05–5.58 °Brix) and TA (0.46–0.49%) of the treated juices are within acceptable limit for fresh hog plum juice [10]. Acidity is a very important factor of juice stability and it is dependent on the nature of the fruit. A similar observation of non-significance of TS treatment on physicochemical attributes of juice from apple, star and blood fruits have been reported [20,21,33].

#### 3.2. Color, cloudiness and browning indices.

The color parameters (CIE \( L^*a^*b^* \)) of raw (49.48, -8.58 and 23.11) and pasteurized (52.81, -10.34 and 24.39) samples, respectively are as shown in Table 3. Notably, TS increased \( L^* \) (lightness) and decreased \( a^* \) (redness) and \( b^* \) (yellowness) which agrees with the previous report on thermosonicated tomatos and red grape juice [34,35]. Color is a vital parameter for microbial safety and sensory quality of juice during processing, storage and consumption [17]. Cloudiness which indicates the level of turbidity and suspended particles in the juice significantly (p < 0.05) reduced from 23.50 to 8.4 after pasteurization (Table 2). Thermosonication increased level of cloudiness from 24.10 (TSa) to 29.30 (TSf). Increase in cloudiness could be ascribed to proteins, lipids, pectins, cellulose and hemi-cellulose present as suspended particles in the juice which are broken down (sonolysis) during cavitation of bubbles [11]. This observation supported the previous report on thermosonicated black mulberry and grape juice [11,24]. Pasteurization significantly (p < 0.05) increased browning index (0.15) compared to the raw juice (0.09) in Table 2. However, samples showed a slight increase in browning index with the treatment period. Increase in browning index with TS could be linked to the development of Maillard reaction [36]. Previous authors’ report on the inefficacy of TS to cause Maillard effect at ≤50 °C could be responsible for its insignificant effect at TSA-H [22,37]. Conversely, TS at elevated temperature could trigger Maillard reaction and thus correlates with the decrease in lightness (\( L^* \)) and yellowness (\( b^* \)) of chroma values at 60 °C (TSf) [35].

### Table 2

| Treatment | pH     | Total soluble solids (“Brix) | Titratable acidity (%) |
|-----------|--------|----------------------------|------------------------|
| Raw Juice | 2.35 ± 0.15° | 5.58 ± 0.14° | 0.46 ± 0.16° |
| Pasteurized Juice | 2.36 ± 0.02° | 5.58 ± 0.14° | 0.49 ± 0.13° |
| TSa       | 2.34 ± 0.02° | 5.57 ± 0.12° | 0.48 ± 0.20° |
| TSb       | 2.33 ± 0.02° | 5.58 ± 0.12° | 0.49 ± 0.12° |
| TSc       | 2.32 ± 0.02° | 5.58 ± 0.14° | 0.49 ± 0.18° |
| TSD       | 2.32 ± 0.02° | 5.58 ± 0.13° | 0.49 ± 0.21° |
| TSE       | 2.33 ± 0.01° | 5.07 ± 0.12° | 0.47 ± 0.20° |
| TSF       | 2.33 ± 0.01° | 5.13 ± 0.12° | 0.49 ± 0.12° |
| TSF       | 2.34 ± 0.01° | 5.13 ± 0.11° | 0.49 ± 0.18° |
| TSG       | 2.34 ± 0.01° | 5.13 ± 0.13° | 0.49 ± 0.21° |
| TSH       | 2.33 ± 0.02° | 5.05 ± 0.09° | 0.47 ± 0.20° |
| TSI       | 2.34 ± 0.01° | 5.07 ± 0.12° | 0.49 ± 0.12° |
| TSJ       | 2.34 ± 0.01° | 5.13 ± 0.12° | 0.48 ± 0.18° |
| TSK       | 2.34 ± 0.01° | 5.13 ± 0.13° | 0.48 ± 0.21° |
| TSL       | 2.34 ± 0.01° | 5.13 ± 0.13° | 0.48 ± 0.21° |

Values are means ± standard deviation of three replicates experiments. Mean values in the same column with the same superscripts are not significantly different (p < 0.05).

3.3. Ascorbic acid content (AA)

The ascorbic acid (AA) contents of raw and pasteurized juice obtained were 24.10 and 11.35 mg/100 ml respectively (Table 3). How-ever, TS significantly (p < 0.05) increased the level of ascorbic acid at 40 °C (TSf) and 50 °C (TSg) reached the effective elimination of dissolved oxygen (which promotes AA stability during processing) in the juice medium during cavitation [11,38], while thermosonicated juice medium was reported [35]. Higher loss of AA with TS treatment at 60 °C (TSf) could also result from severe sonolytic activity occurring during the collapse of...
at 40 °C increased from 8.55 to 9.45 mg GAE/ml (TSA-D), while samples and 7.35 mg GAE/ml respectively (Table 3). During TS, TPC of samples been reported in thermosonicated strawberry juice [37].

bubbles formed via cavitation [40]. A similar observation of AA loss has been reported in thermosonicated strawberry juice [37].

3.4. Total phenolic content (TPC)

The TPC content of raw and pasteurized hog plum juice were 8.01 and 7.35 mg GAE/ml respectively (Table 3). During TS, TPC of samples at 40 °C increased from 8.55 to 9.45 mg GAE/ml (TSA-D), while samples at 50 °C increased from 8.39 to 9.48 mg GAE/ml (TSE-H). However, the reduction in TPC values from 7.83 to 7.61 mg GAE/ml was observed in samples treated at 60 °C (TSI-L). Increase in TPC with TS at 40 and 50 °C could be associated with the release of phenolic compounds (secondary metabolites) from the bond to free form during cavitation [39,41].

Cavitation during TS has been reported to increase mechanical disruption of plant cell wall resulting in the extraction of certain bioactive components [19,42]. Reduced value of TPC at elevated temperature could be linked with processing condition such as temperature, treatment period and power rating [43,44]. A similar observation of reduction was reported in thermosonicated apple juice [21].

3.5. Total carotenoid content (TC)

Effect of TS treatment on carotenoid content which is a precursor of vitamin A with concomitant health-promoting characteristics is as shown in Table 3. Carotenoid content of raw hog plum juice was 95.15 µg/100 ml while that of pasteurized juice was 75.13 µg/100 ml. Thermosonicated samples treated at 40 °C (TSa-D) increased carotenoid content from 86.05 to 97.23 µg/100 ml along the treatment period, while samples treated at 50 °C (TSE-H) increased from 88.26 to 99.24 µg/100 ml. A decline from 69.06 to 67.56 µg/100 ml was observed in samples treated at 60 °C (TSI-L). Increase in carotenoid content from 86.05 to 97.23 µg/100 ml along the treatment period, TS treatment increased antioxidant activity of juice treated at 40 °C (TSa-D) from 49.19 to 71.24%, and juice treated at 50 °C (TSE-H) increased from 45.29 to 87.22%, while juice treated at 60 °C (TSI-L) decreased from 65.29 to 43.33%. Increase in antioxidant activity at 40 and 50 °C could be associated with the bioavailability of phenolic compounds during cavitation [46,47].

3.7. Antioxidant activity

The antioxidant capacities which were measured using the DPPH assay were not significantly (p < 0.05) different from each other (Table 3). The antioxidant activity of raw juice was 38.72% while that of pasteurized juice was 34.96%. However, thermosonication treatment significantly increased the values of antioxidant activity with an increase in the treatment period. TS treatment increased antioxidant activity of juice treated at 40 °C (TSa-D) from 49.19 to 71.24%, and juice treated at 50 °C (TSE-H) increased from 45.29 to 87.22%, while juice treated at 60 °C (TSI-L) decreased from 65.29 to 43.33%. Increase in antioxidant activity at 40 and 50 °C could be associated with the bioavailability of phenolic compounds during cavitation [46,47]. Similar increase with treatment condition has been reported in carrot and golden berry juice [39,50]. Other authors associated increase in antioxidant activity with decreased formation of free hydroxyl radical during TS on the juice component [51,52]. High level of these radicals for a longer period has been reported to have a deleterious impact on the antioxidant activity [18]. This development may be responsible for decreasing antioxidant values at 60 °C.

3.8. Microbial inactivation

Microbial count in Table 4 showed that total plate count, mold and yeast count of raw hog plum juice were 5.23 and 4.51 log CFU/ml respectively. Pasteurized samples showed no detectable microbial growth. After thermosonication treatment at 40 °C (TSa-D), total bacterial count reduced from 3.75 to 1.01 log CFU/ml, while mold and yeast count reduced from 4.17 to 3.64 log CFU/ml. Further TS treatment at 50 and 60 °C showed no detectable growth in the bacterial count, while TS reduced mold and yeast count at 50 °C from 3.36 to 1.93 log CFU/ml, with no detectable growth at 60 °C. Complete inactivation by pasteurization treatment could be associated with rupturing of cell wall/membrane and nuclear components leading to cell death [52]. Microbial inactivation via thermosonication is majorly associated with acoustic cavitation on the cellular structure which could either be transient (producing implosion of bubbles in the liquid) or stable (producing free radicals with antimicrobial properties) in nature.
and grapefruit have been reported [39,55]. However, incomplete in-
formation of thermosonicated juices from carrot, apple, cranberry, pineapple
with TS treatment. However, extended processing time at elevated
color (6.12–6.39), flavor (6.31–6.45), mouth feel (6.22–6.49) and
respectively. However, increase in sensory scores of taste (6.31–6.48),
the same order of parameter were 6.05, 6.11, 6.12, 6.22 and 6.38 re-
crease in sensory scores of taste (6.31–6.48),
values for pasteurized juice in
pasteurized juice (Table 5). In raw juice, sensory scores of taste, color,
scores in all the sensory parameters and overall acceptability than 
and 6.45, respectively. While the sensory scores for pasteurized juice in
Thermosonication significantly improved color parameters, cloudiness
and browning index. It also improved bioactive components such as
Thermosonication as a way of enhancing the quality and consequently its
economic value over conventional pasteurization treatment.
4. Conclusion
In the present study, hog plum juice was subjected to thermo-
sonication as a way of enhancing the quality and consequently its
economic value over conventional pasteurization treatment. Thermosonication significantly improved color parameters, cloudiness
and browning index. It also improved bioactive components such as
ascorbic acid, phenolic, carotenoid, flavonoid and antioxidant activity.
Significant microbial inactivation was obtained, and sensory para-
meters were also enhanced. However, elevated temperature (60 °C) of
TS treatment did not favor most of these quality attributes which may
necessitate further optimization of the treatment parameters for max-
imum quality retention. Furthermore, storage or shelf stability of the
treated juice is open to further investigation for its commercial poten-
tials using this method.

CRediT authorship contribution statement
Adebola O. Oladunjoye: Conceptualization, Methodology, Software,
Validation, Writing - review & editing. Folasade O. Adeboyejo: Visualization, Supervision, Project administration. Titilola
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Writing - original draft. Olaide R. Aderibigbe: Supervision, Project
administration, Funding acquisition.

| Treatment | AA (mg/100 ml) | TPC (mgGAE/ml) | TCC (µg/100 ml) | AC (%) | Total plate count (log CFU/ml) | Yeast and mold count (log CFU/ml) |
|-----------|----------------|----------------|-----------------|--------|-----------------------------|-------------------------------|
| Raw Juice | 24.10 ± 0.15a  | 8.01 ± 0.03b  | 95.15 ± 0.05c  | 38.72 ± 0.55d | 5.32 ± 0.03a                 | 4.51 ± 0.04c                   |
| Pasteurized Juice | 11.35 ± 0.08b | 7.35 ± 0.06c  | 75.13 ± 0.03d  | 34.96 ± 0.23e | ND                          | ND                            |
| TS-A      | 22.40 ± 0.03c  | 8.55 ± 0.04d  | 86.05 ± 0.06e  | 49.19 ± 0.25f | 3.75 ± 0.03b                 | 4.17 ± 0.14c                   |
| TS-B      | 23.95 ± 0.05d  | 8.49 ± 0.34e  | 88.24 ± 0.08f  | 54.54 ± 0.29g | 2.23 ± 0.12c                 | 3.97 ± 0.08d                   |
| TS-C      | 24.15 ± 0.16d  | 9.04 ± 0.31f  | 92.19 ± 0.03g  | 61.17 ± 0.24h | 1.01 ± 0.15i                 | 3.64 ± 0.19j                   |
| TS-D      | 26.85 ± 0.13h  | 9.45 ± 0.23i  | 97.23 ± 0.08j  | 71.24 ± 0.15k | ND                          | ND                            |
| TS-E      | 23.18 ± 0.13k  | 8.39 ± 0.04l  | 88.26 ± 0.18m  | 45.29 ± 0.15n | ND                          | ND                            |
| TS-F      | 25.85 ± 0.08m  | 8.63 ± 0.24n  | 89.06 ± 0.22o  | 58.54 ± 0.10p | ND                          | 2.03 ± 0.17q                   |
| TS-G      | 27.36 ± 0.26p  | 9.14 ± 0.01q  | 95.13 ± 0.17r  | 72.11 ± 0.14s | ND                          | 5.14 ± 0.17t                   |
| TS-H      | 25.87 ± 0.17r  | 9.48 ± 0.22s  | 99.24 ± 0.15t  | 87.22 ± 0.25u | ND                          | ND                            |
| TS-I      | 22.86 ± 0.13v  | 7.83 ± 0.04y  | 89.06 ± 0.18w  | 65.29 ± 0.15x | ND                          | ND                            |
| TS-J      | 22.75 ± 0.08x  | 7.78 ± 0.24z  | 88.78 ± 0.22aa | 58.54 ± 0.10b | ND                          | ND                            |
| TS-K      | 22.67 ± 0.26aa | 7.67 ± 0.01b  | 80.42 ± 0.17c  | 52.11 ± 0.14d | ND                          | ND                            |
| TS-L      | 22.66 ± 0.17c  | 7.61 ± 0.22d  | 77.56 ± 0.15e  | 43.33 ± 0.25f | 5.32 ± 0.03g                 | 4.51 ± 0.04h                   |

Values are means ± standard deviation of three replicates experiments. Mean values in the same column with the same superscripts are not significantly different (p < 0.05).
Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ulsonch.2020.105316.

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