Korean J Food Preserv, 30(2), 321-333 (2023)
https://doi.org/10.11002/kjfp.2023.30.2.321
pISSN: 1738-7248, eISSN: 2287-7428

Korean Journal of Food Preservation
한국식품저장유통학회지

Research Article

Physicochemical properties of *kombucha* with fruit peels during fermentation

과일 껍질을 첨가한 콤부차의 발효 중 이화학적 특성

Tae Yeon Lee, Young Hyoun Yi*

이태연 · 이영현*

Department of Food Science and Technology, Seoul National University of Science & Technology, Seoul 01811, Korea

서울과학기술대학교 식품공학과

Abstract The study investigated the pH, acidity, soluble solids, total sugar, polyphenol, flavonoid, anthocyanin content, 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging, and color of *kombucha* with a variety of added fruit peels during the fermentation process. Pear, grape, plum, orange, apple, and golden kiwi peels were added during fermentation. The pH showed a decrease, while an increase in acidity was observed. An increase in soluble solids, which was higher in most experimental groups than the control group, was also observed. A decrease in total sugar was observed over time. However, an increase was observed in reducing sugar. On Day 0, higher total sugar and reducing sugar were detected in the peel addition group compared with the control group. The antioxidant capacity of polyphenol, flavonoid, anthocyanins, and DPPH radicals scavenging increased with fermentation and was higher in all addition groups, except for pear, compared with the control group. Except for grapes and plums containing high levels of anthocyanins, an increase in the L-value was observed over time, and an increase in the a-value of grapes and plums was also observed ($p<0.05$). The possible utilization of inedible fruit peel in *kombucha* was shown. Applying inedible fruit peels to *kombucha* is proposed to increase antioxidant content and modulate color and pH.

Keywords *kombucha*, fruit peels, fermentation, antioxidant

OPEN ACCESS

Citation: Lee TY, Yi YH. Physicochemical properties of *kombucha* with fruit peels during fermentation. Korean J Food Preserv, 30(2), 321-333 (2023)

Received: December 31, 2022
Revised: March 31, 2023
Accepted: April 04, 2023

***Corresponding author**
Young Hyoun Yi
Tel: +82-2-970-6454
E-mail: youngyi@seoultech.ac.kr

Copyright © 2023 The Korean Society of Food Preservation. This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/4.0) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

1. 서론

콤부차(*kombucha*)는 홍차 또는 녹차에 SCOBY(symbiotic culture of bacteria and yeast)와 설탕을 첨가하고 상온에서 6-10일 발효시켜 얻는다(Reiss, 1994; Villarreal-Soto 등, 2018; Watawana 등, 2015). 약 2,000년 전 동북아시아 대륙으로부터 중앙아시아, 중동 및 유럽으로 퍼져 음용되고 있다(Hartmann 등, 2000; Sreeramulu 등, 2000; Watawana 등, 2015).

SCOBY는 주로 초산균과 내삼투성 효모로 이루어진 symbiotic culture이다(Jayabalan 등,

2014; Kaashyap 등, 2021; Marsh 등, 2014). 발효 중 *Acetobacter xylinum* 등에 의해서 생성된 cellulose film (Blanc, 1996; Chawla 등, 2009; Laavanya 등, 2021)에 bacteria와 yeast가 붙어서 gel 모양의 피막(pellicle)이 형성된다(Sreeramulu 등, 2000).

효모 세포벽에 있는 invertase가 설탕을 포도당과 과당으로 가수분해한다(Koschwanez 등, 2011; Reiss, 1994). 분해된 당이 발효를 거쳐 알코올로 된 후 초산으로 된다. 초산균은 포도당을 이용하여 gluconic, glucuronic, acetic 및 lactic acids 같은 유기산을 생성하여 고유한 풍미와 기능성을 부여한다(Jayabalan 등, 2014; Leal 등, 2018). 콤부차의 항미생물(Battikh 등, 2012; Sreeramulu 등, 2000), 항산화(Chu와 Chen, 2006)와 항암성(Jayabalan 등, 2011; Srihari 등, 2013)도 보고되었다.

전 세계 콤부차 시장 규모는 2021년 기준으로 약 3조 4천억 원이며 2030년까지 연평균 성장률은 15.6%로 예상된다(Grand View Research, 2022). 국내 콤부차는 중소기업에서 2018년에 시작하였고, 2021년에는 대기업에서도 제품을 출시하였다. 한 기업의 2020년 매출은 205억 원에서 2021년 407억 원으로 거의 100%에 가까운 성장을 했다(Ha, 2022).

과일은 가식 부위 과육과 비가식 부위 껍질이나 씨로 나뉜다. 과육의 항산화(Hassimotto 등, 2005; Saravanan과 Parimelazhagen, 2014), 항미생물(Saravanan과 Parimelazhagan, 2014)과 항당뇨(Saravanan과 Parimelazhagan, 2014; Sharma 등, 2006)가 보고되었다. 과육을 아이스크림(EL-Samahy 등, 2009), 맥주(Alves 등, 2020), 요구르트(Sengul 등, 2012), 치즈(Ramteke 등, 2020) 등에 첨가하여 식감, 기능성 및 풍미를 향상시켰다.

한국의 과일 생산액은 2005년 2조 5,290억 원에서 2019년 4조 1,879억 원으로 매년 꾸준히 증가했다(Yoon 등, 2021). Ruiz-Torralba(2018)에 따르면 52종 과일의 평균 비가식 부위는 약 16%이다. 과일 생산 증가에 따라 비가식 부위인 껍질과 씨의 증가가 추정된다. 석류(Fawole 등, 2012)와 바나나(Ehiowemwenguan 등, 2014) 껍질의 항미생물 그리고 오렌지(Hegazy와 Ibrahium, 2012)와 사과(Wolfe 등, 2003) 껍질의 항산화 효과도 보고되었다.

콤부차의 경우, snake furit(Zubaidah 등, 2019), red raspberry와 blackthorn(Ulusoy와 Tamer, 2019), 그리고 blackberry와 red goji berry(Akarca, 2022) 과육 활용 시 항산화 효과가 증가되었지만 미활용 껍질 활용 연구는 미미한 실정이다. 만약 미활용 껍질을 활용한다면 색, 맛, 향과 기능성 성분의 증진뿐만 아니라, 음식물 쓰레기 처리비용 및 관련 시설 설치와 유지비 절감이 기대된다. 본 연구에서는 껍질을 넣은 콤부차의 특성과 제품 가능성을 검토하기 위해서 발효 중 pH, 산도, 가용성 고형분, 총당, 환원당, 폴리페놀, 플라보노이드, 안토시아닌 함량, DPPH(2,2-diphenyl-1-picrylhydrazyl) 라디칼 소거능 및 색도를 조사하였다.

2. 재료 및 방법

2.1. 실험 재료

SCOBY와 콤부차는 Y-Biotic(Y-biotic Co., Ltd., Seoul, Korea)에서 구매하였다. 홍차잎(Ceylon Tea, Ahmad Tea Ltd., Ras Al Khaimah, UAE), 설탕(Samyang Co., Ltd., Ulsan, Korea), 배(*Pyrus pyrifolia*), 포도(*Vitis vinifera*), 자두(*Prunus salicina*), 오렌지(*Citurs sinensis*), 사과(*Malus domestica*)와 골드키위(*Actinidia chinensis*)는 시중에서 구매하여 사용했다.

2.2. 과일 건조

분리한 과피를 60℃에서 4시간 건조(JSOF-150, JS Research Inc., Gongju, Korea) 후 믹서기(WSG-9100, Joong San Co., Ltd., Seoul, Korea)로 분쇄했다. 과피 가루를 ziploc(Thai griptech Co., Ltd., Bangkok, Thailand)에 넣어 밀봉한 후 -20℃ 냉장고(R-B63AM, LG Electronics Inc., Seoul, Korea)에 사용 시까지 보관하였다(Sogi 등, 2013).

2.3. 콤부차 제조

물 1.0 L를 전기 포트(P-5580TP, Zhongshan Xinhao Electric Co., Ltd., Zhongshan, China)에서 80℃까지 끓였다. 홍차잎 6 g이 담긴 티백(DP-5580TP, Zhongshan Xinhao Electric Co., Ltd., Zhongshan, China)을 넣고 15분간 우려 홍차를 만들었다. 홍차 395 mL와 설탕 50 g을 Clear Laboratory Bottle(BWK Life Sciences, Mainz,

https://doi.org/10.11002/kjfp.2023.30.2.321

Germany)에서 섞고 식힌 후 SCOBY 25 g과 콤부차 30 mL를 첨가하였다. 면포를 씌워 25℃에서 12일간 배양하여 대조구를 제조했다(Neffe-Skocinska 등, 2017). 실험구는 면포를 씌우기 전 건조된 과피 10 g을 첨가하였다(Table 1).

2.4. pH 측정

시료 20 mL를 100 mL 비커에 담아 pH meter(Strarter 3100, Ohaus Instrument Co., Ltd., NJ, USA)로 발효 0일부터 12일까지 매 3일 간격으로 측정하였다(Ko 등, 2017).

2.5. 산도 측정

시료 10배 희석액 10 mL를 Petri dish(SPL Co., Ltd., Pocheon, Korea)에 넣고 1%(v/v) phenolphthalein (Daejung Chemicals & Metals Co., Ltd., Daegu, Korea) 지시약을 2-3방울 넣었다. Burette을 이용하여 0.1N NaOH(Samchun Pure Chemical Co., Ltd., Pyeongtaek, Korea)를 첨가하여 pH 8.3까지 적정하였다. NaOH 소비량을 아래 식에 대입하여 산도(%)를 구했다(Ko 등, 2017).

$$\text{산도(\%)} = \frac{0.1\text{N NaOH 소비량} \times \text{NaOH 역가} \times 0.006 \times \text{희석배수}}{\text{시료량(mL)}} \times 100$$

2.6. 가용성 고형분 측정

당도계(Master Refractometer, Atago Co., Ltd., Tokyo, Japan)로 20℃ 시료를 측정하여 °Brix로 나타내었다(Kwon 등, 2012).

2.7. 총당 측정

Glucose(Sigma Aldrich Co., Saint Louis, MO, USA) 용액 0-100 μg/mL를 spectrophotometer(Genesys 10 UV, Thermo Scientific, Inc., Waltham, MA, USA) 480 nm에서 측정하여 standard curve를 만들었다. 적정하게 희석한 시료 1 mL를 15 mL conical tube(SPL Life Science Co., Ltd., Pocheon, Korea)에 넣고 95%(v/v) sulfuric acid(Daejung Chemicals & Metals Co., Ltd., Daegu, Korea) 3 mL를 첨가한 후 1분간 실내에 놔두었다. 실온의 water bath(BW-20G, Jeio Tech Co., Ltd., Daejon, Korea)에 넣어 식힌 후 90%(v/v) phenol (Daejung Chemicals & Metals Co., Ltd., Daegu, Korea) 50 μL를 넣고 섞었다. 상온에 30분간 놔둔 후 480 nm에서 측정한 흡광도를 회귀곡선식에 대입하여 총당 함량(%)을 나타냈다(Salari 등, 2019).

2.8. 환원당 측정

시료 1 mL를 15 mL conical tube에 넣고 DNS(3,5-dinitro salicylic acid) reagent 1 mL를 첨가했다. Water bath 100℃에서 5분간 놔둔 후 상온에서 식혔다. 증류수를 넣어 8 mL로 보정하고 spectrophotometer 540 nm에서 흡광도를 측정했다. Glucose standard curve를 이용하여 환원당 함량(%)으로 나타냈다(Aung과 Eun, 2021).

2.9. 폴리페놀 함량 측정

Pipet으로 10배 희석된 시료 0.1 mL를 15 mL conical tube에 넣고 10%(v/v) Folin-Ciocalteau reagent(Sigma Aldrich Co., Saint Louis, MO, USA) 0.75 mL를 첨가했다. 상온에서 10분간 놔둔 후 2%(w/v) sodium carbonate (Daejung Chemical & Metals Co., Ltd., Siheung,

Table 1. Composition of *kombucha*

Ingredient	Control	Korean pear	Grape	Plum	Orange	Apple	Golden kiwifruit
SCOBY (g)	25	25	25	25	25	25	25
Kombucha (mL)	30	30	30	30	30	30	30
Sugar (g)	50	50	50	50	50	50	50
Black tea (mL)	395	395	395	395	395	395	395
Fruit peel (g)	0	10	10	10	10	10	10

Korea) 0.75 mL를 넣었다. 암실에서 45분 놔둔 후 spectrophotometer 765 nm에서 흡광도를 측정했다. Gallic acid(Sigma Aldrich Co., Saint Louis, MO, USA) standard curve를 이용하여 폴리페놀 함량(%)으로 표시했다(Lu 등, 2011).

2.10. 플라보노이드 함량 측정

시료 4배 희석액 0.5 mL, 10%(w/v) aluminum choride (Junsei Chemical Co., Ltd., Tokyo, Japan) 0.1 mL, 1M potassium acetate(Lugen Sci. Co., Ltd., Seoul, Korea) 0.1 mL와 증류수 2.8 mL를 15 mL conical tube에 넣고 섞어주었다. 상온에서 30분간 방치한 후 spectrophotometer 415 nm에서 흡광도를 측정했다. Quercetin(Sigma Aldrich Co., Saint Louis, MO, USA) standard curve를 이용하여 flavonoid 함량(%)으로 표현했다(Shahbazi 등, 2018).

2.11. 안토시아닌 함량 측정

비커에 0.2M potassium chloride(Junsei Chemical Co., Ltd., Tokyo, Japan) 125 mL와 0.2M hydrochloric acid(Daejung Chemicals & Metals Co., Ltd., Daegu, Korea) 375 mL를 혼합하여 pH 1.0 buffer solution으로 그리고 1M sodium actate(Daejung Chemicals & Metals Co., Ltd., Daegu, Korea) 400 mL, 1M hydrochloric acid 240 mL와 증류수 360 mL로 pH 4.5 buffer solution을 만들었다. 시료 0.5 mL가 담긴 conical tube에 각각의 buffer solution을 따로 넣고 512와 700 nm에서 흡광도를 측정하였으며, 아래 식에 대입하여 안토시아닌 함량을 구했다(Ulusoy와 Tamer, 2019).

$$\text{총안토시아닌 함량} = \frac{A \times MW \times Df \times 1{,}000}{\varepsilon \times I}$$

$A = (A_{\lambda 512} - A_{\lambda 700})$ of pH 1.0 buffer solution - $(A_{\lambda 512} - A_{\lambda 700})$ of pH 4.5 buffer solution

MW = Molecular weight (449.2 for cyanidin-3-glucoside)

Df = Dilution factor

ε = Absorbance coefficient (26,900)

I = Path length of cuvette (1 cm)

2.12. DPPH 라디칼 소거능 측정

Methanol(Samchun Pure Chemical Co., Ltd., Pyeongtaek, Korea) 99.5%(v/v)로 40배 희석한 시료 0.5 mL를 15 mL conical tube에 넣고 0.1 mM DPPH 용액 1.5 mL(Alfa Aesar, Inc., Tewksbury, MA, USA)를 첨가하였다. 실온의 암실에 20분간 둔 후 spectrophotometer 517 nm에서 실험구 흡광도를 얻었다. 공시료는 시료 희석액 대신 메탄올을 사용하였다. 각각의 흡광도를 아래 식에 대입하여 소거능(%)을 구했다(Kaewkod 등, 2019).

$$\text{DPPH 라디칼 소거능(\%)} = \frac{\text{공시료의 흡광도} - \text{실험구의 흡광도}}{\text{공시료의 흡광도}} \times 100$$

2.13. 색도 측정

직경 5.5 cm와 높이 1.2 cm Petri dish(Doowon Meidite. Co., Ltd., Yongin, Korea)에 콤부차 4 mL를 넣고 색채색차계(CR-20, Konica Minolta, Inc., Tokyo, Japan)를 이용하여 측정했다. 색도는 명도를 나타내는 L값, 적색도를 나타내는 a값과 황색도를 나타내는 b값으로 나타냈다(Cho 등, 2006).

2.14. 통계처리

측정 결과는 SPSS program(ver. 26.0, SPSS Inc., Chicago, IL, USA)을 이용하여 분산 분석(ANOVA)을 하였다. 유의적 차이가 있는 경우 Duncan법을 이용하여 $p<0.05$ 수준에서 유의성 검증을 하였다.

3. 결과 및 고찰

3.1. pH

콤부차 pH는 미생물의 성장과 물리화학적 변화 및 발효 진행의 지표가 된다(Hur 등, 2014; Malbasa 등, 2008). 발효 중 pH는 Table 2와 같이 Day 0, pH 3.08-3.44에서 Day 12, pH 2.40-2.81로 감소하였다($p<0.05$). 미생물에 의해 생성된 acetic acid나 gluconic acid와 같은 유기산

https://doi.org/10.11002/kjfp.2023.30.2.321

Table 2. pH of *kombucha* with fruit peels during fermentation at 25℃

Day	Control	Korean pear	Grape	Plum	Orange	Apple	Golden kiwifruit
0	3.08±0.04$^{Ea1)2)3)}$	3.15±0.02^{Da}	3.15±0.01^{Da}	3.08±0.04^{Ea}	3.44±0.02^{Aa}	3.33±0.32^{Ba}	3.29±0.03^{Ca}
3	2.99±0.04^{Eb}	3.09±0.01^{Cb}	3.08±0.02^{Cb}	2.86±0.01^{Fb}	3.28±0.04^{Ab}	3.13±0.01^{Bb}	3.05±0.01^{Db}
6	2.64±0.03^{Fc}	2.84±0.02^{Bc}	2.82±0.02^{Cc}	2.72±0.01^{Ec}	2.91±0.02^{Ac}	2.76±0.02^{Dc}	2.92±0.01^{Ac}
9	2.52±0.02^{Fd}	2.70±0.02^{Cd}	2.70±0.01^{Cd}	2.63±0.01^{Ed}	2.81±0.01^{Bd}	2.66±0.02^{Dd}	2.89±0.01^{Ad}
12	2.40±0.01^{Ee}	2.49±0.01^{Ce}	2.49±0.01^{Ce}	2.44±0.02^{De}	2.63±0.02^{Be}	2.44±0.01^{De}	2.81±0.02^{Ae}

$^{1)}$All values are presented as mean±SD (n=5).
$^{2)A-G}$Means within a row not followed by the same letter are significantly different (p<0.05).
$^{3)a-e}$Means within a column not followed by the same letter are significantly different (p<0.05).

에 의해 pH가 감소한 것으로 여겨지며, Sreeramulu 등(2000), Tanticharakunsiri 등(2020) 그리고 Aung과 Eun(2021)의 결과와 유사하였다.

3.2. 산도

총산 함량은 콤부차의 독특한 맛과 향에 영향을 미친다(Leal 등, 2018). 발효 중 생성된 유기산(Sreeramulu 등, 2000)에 의해서 Day 0, 1.2-1.4에서 Day 12, 8.9-20.3%(Table 3)로 증가하여 Sreeramulu 등(2000), Tanticharakunsiri 등(2020) 그리고 Aung과 Eun(2021)과 유사한 경향을 보였으며, pH(Table 2) 감소와도 부합하였다. 자두의 산도가 가장 높은(p<0.05) 것은 배, 사과(Omer과 Matjafri, 2013)와 골든키위(Jeong 등, 2007)보다 높은 자두 과육(Jung 등, 2006)의 산도에 기인하는 것으로 보인다.

3.3. 가용성 고형분

가용성 고형분은 식품 속에 녹아있는 모든 유기물과 무기물의 함량이다(Zubaidah 등, 2019). Day 0, 8.8-9.8에서 Day 12, 10.2-13.2 °Brix(Table 4)로 증가(p<0.05)하였다. 실험구가 대조구보다 높은 경향을 보였으며, 껍질의 비타민과 같은 수용성 성분 용출에 기인하는 것으로 보인다(Zhou 등, 2019).

3.4. 총당

Day 0, 9.78-10.86에서 Day 12, 5.97-7.48%(Table 5)로 감소하였는데, 미생물이 당을 이용하여 SCOBY의 cellulose 및 유기산을 생산(Zubaidah 등, 2019)한 것으로 여겨진다. Zahid 등(2022)의 연구처럼 요거트에 과일껍질 첨가가 총당을 증가시키듯 동일한 발효일에는 실험구가 대조구보다 높았다. 당 함량이 높은 포도 껍질(Maurer 등, 2019)은 동일 발효일에 다른 실험구보다 같거나 높게 나타났다(p<0.05).

3.5. 환원당

환원당은 유리 알데하이드기 또는 케톤기를 가지고 있어 환원제 역할을 할 수 있는 당이다. 일부 다당류, 이당류 그리

Table 3. Total acid (%) of *kombucha* with fruit peels during fermentation at 25℃

Day	Control	Korean pear	Grape	Plum	Orange	Apple	Golden kiwifruit
0	1.3±0.25$^{ABCe1)2)3)}$	1.3±0.18^{ABCe}	1.4±0.28^{ABe}	1.4±0.29^{Ae}	1.3±0.22^{ABCe}	1.2±0.13^{BCe}	1.2±0.01^{Ce}
3	2.5±0.31^{CDd}	2.7±0.31^{Cd}	2.9±0.22^{Bd}	5.2±0.29^{Ad}	2.4±0.24^{DEd}	2.30±0.31^{Ed}	3.0±0.64^{Bd}
6	5.0±0.27^{Cc}	4.5±0.36^{Dc}	5.6±0.30^{Bc}	6.7±0.31^{Ac}	3.2±0.30^{Fc}	3.5±0.25^{Ec}	5.6±0.29^{Bc}
9	8.0±0.30^{Eb}	8.8±0.29^{Db}	9.3±0.31^{Cb}	13.4±0.39^{Ab}	4.4±0.27^{Fb}	9.2±0.30^{Cb}	12.2±0.58^{Bb}
12	12.5±0.38^{Ea}	15.9±0.60^{Da}	17.5±0.38^{Ca}	20.3±0.47^{Aa}	8.9±0.40^{Fa}	18.4±0.30^{Ba}	18.6±0.53^{Ba}

$^{1)}$All values are presented as mean±SD (n=5).
$^{2)A-G}$Means within a row not followed by the same letter are significantly different (p<0.05).
$^{3)a-e}$Means within a column not followed by the same letter are significantly different (p<0.05).

Table 4. Total soluble solid (°Brix) of *kombucha* with fruit peels during fermentation at 25℃

Day	Control	Korean pear	Grape	Plum	Orange	Apple	Golden kiwifruit
0	8.8±0.17$^{Ee1)2)3)}$	9.2±0.00^{Ce}	9.2±0.09^{Ce}	9.2±0.09^{Ce}	9.8±0.09^{Ae}	9.4±0.09^{Be}	9.0±0.15^{De}
3	9.4±0.09^{Fd}	9.7±0.09^{Dd}	10.1±0.09^{Cd}	9.6±0.00^{DEd}	10.5±0.18^{Ad}	10.3±0.17^{Bd}	9.6±0.09^{Ed}
6	9.8±0.17^{Fc}	10.2±0.17^{Dc}	10.4±0.00^{Cc}	9.9±0.09^{Ec}	10.8±0.17^{Bc}	11.9±0.09^{Ac}	9.8±0.15^{EFc}
9	10.2±0.15^{Db}	11.1±0.09^{Cb}	11.1±0.09^{Cb}	10.2±0.15^{Db}	11.9±0.30^{Bb}	12.7±0.17^{Ab}	10.0±0.15^{Eb}
12	10.7±0.17^{Ea}	12.0±0.09^{Da}	12.2±0.09^{Ca}	10.4±0.15^{Fa}	12.7±0.30^{Ba}	13.2±0.15^{Aa}	10.2±0.15^{Ga}

1)All values are presented as mean±SD (n=5).
2)A-GMeans within a row not followed by the same letter are significantly different ($p<0.05$).
3)a-eMeans within a column not followed by the same letter are significantly different ($p<0.05$).

Table 5. Total sugar (%) of *kombucha* with fruit peels during fermentation at 25℃

Day	Control	Korean pear	Grape	Plum	Orange	Apple	Golden kiwifruit
0	9.78±0.17$^{Eb1)2)3)}$	10.10±0.22^{Db}	10.82±0.25^{Ab}	10.26±0.26^{Cb}	10.86±0.26^{Ab}	10.75±0.12^{Aa}	10.51±0.25^{Ba}
3	9.94±0.17^{Ea}	10.39±0.29^{Da}	11.27±0.24^{Aa}	10.45±0.33^{CDa}	11.13±0.23^{Aa}	10.96±0.22^{Ba}	10.58±0.25^{Ca}
6	8.29±0.34^{Ec}	8.46±0.23^{DEc}	9.51±0.40^{Ac}	8.60±0.189^{CDc}	9.04±0.32^{Bc}	8.76±0.33^{Cb}	8.68±0.29^{Cb}
9	6.42±0.20^{Dd}	6.74±0.34^{Cd}	7.90±0.35^{Ad}	6.87±0.30^{Cd}	7.71±0.51^{ABd}	7.50±0.56^{Bc}	6.86±0.31^{Cc}
12	5.97±0.27^{Ee}	6.55±0.21^{De}	7.48±0.27^{Ae}	6.77±0.26^{Cd}	7.25±0.43^{Be}	7.12±0.33^{Bd}	6.66±0.37^{CDd}

1)All values are presented as mean±SD (n=5).
2)A-GMeans within a row not followed by the same letter are significantly different ($p<0.05$).
3)a-eMeans within a column not followed by the same letter are significantly different ($p<0.05$).

고 모든 단당류가 이에 속하며, 과당, 포도당과 galactose가 대표적이다(Dimowo 등, 2021). Day 0에 총당과 같이 껍질 첨가군이 대조군보다 높았고, Day 0, 0.95-2.25에서 Day 12, 7.83-13.69%(Table 6)로 증가($p<0.05$)하였다. 비환원당인 sucrose가 환원당인 포도당과 과당으로 분해되었기 때문이라 여겨지며(Loncar 등, 2014; Siever 등, 1995), Aung과 Eun(2021)의 결과와 유사하였다.

3.6. 폴리페놀 함량

콤부차의 폴리페놀은 찻잎에서 추출되며(Coelho 등, 2020), 항산화능에 기여하는 주요 물질이다. 발효가 진행될수록 증가하여 Tanticharakunsiri 등(2020) 및 Zubaidah 등(2019)의 보고와 같았다. 발효 중 thearubigins가 탈중합되어 항산화 활성이 더 높은 작은 분자로 되거나, 미생물에서 나온 효소가 복잡한 폴리페놀을 작은 분자로 분해하기 때문

Table 6. Reducing sugar (%) of *kombucha* with fruit peels during fermentation at 25℃

Day	Control	Korean pear	Grape	Plum	Orange	Apple	Golden kiwifruit
0	0.95±0.03$^{Ge1)2)3)}$	1.06±0.02^{Fe}	1.14±0.03^{Ee}	1.26±0.03^{De}	1.35±0.04^{Ce}	2.25±0.07^{Ae}	1.67±0.07^{Be}
3	2.34±0.07^{Ed}	2.66±0.06^{Dd}	3.17±0.04^{Cd}	3.37±0.08^{Ad}	2.21±0.06^{Fd}	2.67±0.06^{Dd}	3.21±0.06^{Bd}
6	8.75±0.19^{Dc}	8.15±0.11^{Ec}	10.05±0.11^{Bc}	10.56±0.11^{Ac}	5.20±0.12^{Gc}	7.86±0.09^{Fc}	9.05±0.11^{Cc}
9	11.28±0.20^{Db}	11.23±0.22^{Db}	12.56±0.15^{Bb}	12.81±0.19^{Ab}	6.70±0.19^{Fb}	10.31±0.21^{Eb}	12.03±0.12^{Cb}
12	12.58±0.27^{Ca}	12.23±0.30^{Da}	13.69±0.12^{Aa}	13.16±0.10^{Ba}	7.83±0.41^{Fa}	11.68±0.23^{Ea}	12.20±0.14^{Da}

1)All values are presented as mean±SD (n=5).
2)A-GMeans within a row not followed by the same letter are significantly different ($p<0.05$).
3)a-eMeans within a column not followed by the same letter are significantly different ($p<0.05$).

https://doi.org/10.11002/kjfp.2023.30.2.321

이라 여겨진다(Ulusoy와 Tamer, 2019). 동일 발효일에는 배를 제외하고 모든 실험구가 대조구보다 높았다(Table 7). 자두는 Day 3에서 급격히 증가한 후 항상 다른 시료보다 높았는데(p<0.05), 높은 자두 껍질의 폴리페놀(Lee 등, 2012)의 영향을 받은 것으로 보인다.

3.7. 플라보노이드 함량

플라보노이드는 관속식물에 광범위하게 존재하는 페놀화합물(Dwiputri와 Feroniasanti, 2019)로 콤부차의 주요 항미생물 성분이다(Bhattacharya 등, 2016). SCOBY의 미생물이 폴리페놀을 분해하여 플라보노이드를 생성(Dwiputri와 Feroniasanti, 2019)하듯이 시간이 지날수록 증가(Table 8)하였다. 폴리페놀과 같이 자두도 Day 3에서 급격히 증가하였고 다른 시료보다 높았다(p<0.05).

3.8. 안토시아닌 함량

안토시아닌은 밝은 색을 띠는 포도, red onion, red cabbage 등에 있으며, 색과 맛에 기여한다(Ayed 등, 2016). 색을 띤 과일을 첨가한 콤부차의 안토시아닌이 많은 것(Ulusoy와 Tamer, 2019)처럼 대부분의 실험구가 대조구보다 높은 경향을 보였다. 과피의 안토시아닌(Shehata 등, 2020; Shim 등, 1994) 함량 순서와 동일하게 사과, 자두와 포도로 나타났다(p<0.05). Day 3에서 자두와 포도의 급격한 증가는 플라보노이드(Table 8) 변화와 유사하였고, Day 6부터 자두의 감소(Table 9)는 미생물이 안토시아닌을 활용(Ayed 등, 2016)한 것으로 보인다.

3.9. DPPH 라디칼 소거능

유리기는 산화적 손상을 일으켜 노화를 촉진시키지만 페놀화합물과 결합하여 안정화된다. 유리기 DPPH의 전자 공여 기능을 측정하여 소거능으로 표현한다. 폴리페놀과 플라보노이드의 증가에 따라 소거능도 증가하였다(Table 10). 음용이 권장되는 Day 9부터(Reiss, 1994) 배와 자두를 제외한 모든 시료가 대조구보다 높았다(p<0.05). 배는 낮은 폴리페놀(Table 7) 및 플라보노이드(Table 8), 그리고 자두 폴리페놀의 제한적 DPPH 소거능(Lee 등, 2012)에 기인하는 것으로 보인다.

Table 7. Total phenolic contents (μg/mL) of *kombucha* with fruit peels during fermentation at 25℃

Day	Control	Korean pear	Grape	Plum	Orange	Apple	Golden kiwifruit
0	616.04±10.25[Fe1)2)3)]	477.07±13.31[Ge]	638.50±11.02[Ed]	672.37±6.26[De]	688.58±4.83[Ce]	716.09±18.31[Be]	726.66±10.55[Ae]
3	638.50±10.97[Fd]	489.20±8.73[Gd]	687.86±18.09[Ec]	767.97±12.06[Ad]	699.39±9.84[Dd]	736.51±7.50[Cd]	743.95±5.85[Bd]
6	653.63±8.25[Dc]	500.37±7.42[Ec]	756.92±5.23[Bb]	782.27±13.80[Ac]	705.04±7.57[Cc]	756.92±5.51[Bc]	760.65±6.35[Bc]
9	668.28±8.50[Eb]	513.94±5.19[Fb]	768.57±5.53[Ca]	795.00±8.26[Ab]	711.76±10.15[Db]	769.30±6.00[Cb]	775.66±5.38[Bb]
12	684.50±9.39[Ea]	529.08±9.59[Fa]	774.22±7.70[Ca]	818.66±7.44[Aa]	730.62±10.32[Da]	777.34±4.90[Ca]	785.27±6.87[Ba]

1)All values are presented as mean±SD (n=5).
2)A-GMeans within a row not followed by the same letter are significantly different (p<0.05).
3)a-eMeans within a column not followed by the same letter are significantly different (p<0.05).

Table 8. Total flavonoid contents (μg/mL) of *kombucha* with fruit peels during fermentation at 25℃

Day	Control	Korean pear	Grape	Plum	Orange	Apple	Golden kiwifruit
0	38.70±1.26[De1)2)3)]	36.23±1.08[Ee]	34.07±1.29[Fe]	41.83±1.53[Ce]	45.78±1.84[Be]	51.05±1.93[Ae]	36.92±1.18[Ee]
3	41.92±1.04[Ed]	38.55±1.68[Fd]	44.74±1.69[Dd]	67.18±1.75[Ad]	52.02±1.72[Cd]	53.40±1.58[Bd]	38.99±1.67[Fd]
6	43.84±0.81[Ec]	40.22±1.36[Fc]	46.48±1.01[Dc]	70.18±0.97[Ac]	54.02±1.58[Cc]	55.72±1.47[Bc]	40.53±2.01[Fc]
9	45.73±0.82[Eb]	41.44±1.20[Gb]	49.59±1.02[Db]	72.51±0.98[Ab]	55.50±1.52[Cb]	57.13±1.54[Bb]	43.18±1.12[Fb]
12	46.99±1.15[Ea]	43.44±1.44[Ga]	51.11±1.17[Da]	74.87±1.54[Aa]	56.95±1.98[Ca]	58.87±1.56[Ba]	45.29±1.02[Fa]

1)All values are presented as mean±SD (n=5).
2)A-GMeans within a row not followed by the same letter are significantly different (p<0.05).
3)a-eMeans within a column not followed by the same letter are significantly different (p<0.05).

Table 9. Total anthocyanins contents (mg/100L) of the *kombucha* with fruit peels during fermentation at 25℃

Day	Control	Korean pear	Grape	Plum	Orange	Apple	Golden kiwifruit
0	ND[1)2)3)4)]	ND	317±7.02^{Ab}	153±2.68^{Bd}	2±1.31^{Ca}	18±2.30^{Ca}	ND
3	ND	ND	2,124±5.35^{Aa}	375±6.67^{Ba}	ND	15±1.67^{Ca}	ND
6	ND	ND	2,123±6.77^{Aa}	343±6.66^{Bb}	ND	14±3.05^{Ca}	ND
9	1±0.27^{Ca}	ND	2,103±.98^{Aa}	324±8.89^{Bc}	1±0.63^{Ca}	17±3.18^{Ca}	ND
12	1±0.07^{Ca}	ND	2,099±9.36^{Aa}	316±8.76^{Bc}	1±0.17^{Ca}	17±4.78^{Ca}	ND

1)All values are presented as mean±SD (n=5).
2)A–GMeans within a row not followed by the same letter are significantly different ($p<0.05$).
3)a–eMeans within a column not followed by the same letter are significantly different ($p<0.05$).
4)ND, not detected.

Table 10. DPPH radical scavenging activity (%) of *kombucha* with fruit peels during fermentation at 25℃

Day	Control	Korean pear	Grape	Plum	Orange	Apple	Golden kiwifruit
0	85.61±0.94^{Bd}[1)2)3)]	76.80±1.26^{Ed}	80.08±0.84^{Dd}	76.87±1.19^{Ee}	83.76±0.90^{Ce}	87.64±1.17^{Ad}	85.49±1.31^{Bd}
3	86.74±1.41^{Bc}	77.65±1.02^{Fc}	80.42±0.65^{Dd}	79.64±1.03^{Ed}	84.21±0.0^{Cd}	88.27±1.10^{Ac}	86.12±1.27^{Bc}
6	87.44±0.90^{Cb}	78.08±0.65^{Fc}	87.96±0.73^{Bc}	83.20±1.53^{Ec}	86.72±0.58^{Dc}	89.19±0.28^{A0b}	88.92±0.53^{Ab}
9	88.04±0.37^{Ea}	80.29±0.38^{Gb}	89.02±0.33^{Cb}	85.42±0.33^{Fb}	88.67±0.23^{Db}	89.67±0.31^{Aa}	89.46±0.34^{Bab}
12	88.50±0.40^{Ca}	81.53±0.62^{Ea}	90.04±0.28^{Aa}	86.88±0.52^{Da}	89.15±0.26^{Ba}	89.82±0.37^{Aa}	89.90±0.26^{Aa}

1)All values are presented as mean±SD (n=5).
2)A–GMeans within a row not followed by the same letter are significantly different ($p<0.05$).
3)a–eMeans within a column not followed by the same letter are significantly different ($p<0.05$).

3.10. 색도

콤부차 색은 폴리페놀 함량에 영향을 받는다(Abuduaibifu와 Tamer, 2019). 발효 중 색을 띠는 thearubigins 변화(Chu와 Chen 등, 2006)에 따라 자두와 포도를 제외하고 L값은 증가하였다. 자두와 포도의 높은 anthocyanins (Table 9)로 L값은 감소하였고 a값은 증가($p<0.05$)한 것으로 보인다(Table 11).

4. 요약

배, 포도, 자두, 오렌지, 사과와 골든키위 껍질을 첨가한 콤부차의 pH, 산도, 가용성 고형분, 총당, 환원당, 폴리페놀

Table 11. Hunter color value of the *kombucha* with fruit peels during fermentation at 25℃

	Day	Control	Korean pear	Grape	Plum	Orange	Apple	Golden kiwifruit
L	0	48.9±0.63^{Ae}[1)2)3)]	49.1±0.53^{Ae}	47.7±0.43^{Ba}	46.6±1.88^{Ca}	49.2±0.46^{Ae}	48.7±1.02^{Ad}	49.3±0.34^{Ae}
	3	49.7±0.28^{BCd}	49.7±0.56^{BCd}	42.8±0.75^{Eb}	45.9±2.09^{Dab}	50.4±0.35^{Ad}	49.2±0.34^{Cc}	49.9±0.43^{ABd}
	6	50.6±0.41^{ABc}	50.4±0.26^{ABc}	36.2±2.41^{Dc}	45.5±2.42^{Cab}	51.0±0.27^{Ac}	49.9±0.38^{Bb}	50.6±0.33^{ABc}
	9	50.9±0.29^{Bb}	50.8±0.31^{Bb}	35.3±0.81^{Dd}	45.2±2.64^{Cab}	51.7±0.312^{Ab}	50.5±0.34^{Ba}	51.0±0.31^{Bb}
	12	51.3±0.39^{Ba}	51.1±0.20^{Ba}	35.2±0.55^{Dd}	44.4±2.77^{Cb}	52.3±0.37^{Aa}	50.8±0.48^{Ba}	51.3±0.58^{Ba}
a	0	0.7±0.12^{Da}	0.7±0.13^{Da}	3.2±0.18^{Be}	10.6±0.31^{Ae}	0.0±0.14^{Fa}	0.9±0.25^{Ce}	0.5±0.14^{Ea}
	3	0.5±0.17^{Db}	0.6±0.14^{Db}	12.6±0.62^{Ad}	12.0±0.57^{Bd}	−0.4±0.17^{Fb}	1.2±0.24^{Cd}	0.2±0.12^{Eb}
	6	0.4±0.07^{Dbc}	0.5±0.09^{Dc}	28.6±0.95^{Aa}	12.4±0.30^{Bc}	−0.4±0.17^{Fb}	1.4±0.13^{Cc}	0.0±0.11^{Ec}
	9	0.3±0.35^{Dcd}	0.4±0.09^{Dc}	25.5±0.46^{Ab}	12.9±0.28^{Bb}	−0.6±0.16^{Fc}	1.5±0.13^{Cb}	−0.2±0.12^{Ed}
	12	0.3±0.33^{Dd}	0.4±0.08^{Dc}	24.5±0.95^{Ac}	13.3±0.31^{Ba}	−0.7±0.11^{Fd}	1.8±0.22^{Ca}	−0.3±0.10^{Ed}

https://doi.org/10.11002/kjfp.2023.30.2.321

(continued)

	Day	Control	Korean pear	Grape	Plum	Orange	Apple	Golden kiwifruit
b	0	6.4±0.43^{Aa}	5.7±0.73^{Ba}	4.8±0.49^{Ca}	4.1±0.73^{Da}	6.6±0.34^{Aa}	6.4±0.28^{Aa}	6.5±0.34^{Aa}
	3	5.9±0.45^{Ab}	5.1±0.72^{Cb}	1.6±0.35^{Eb}	3.4±0.37^{Db}	4.9±0.32^{Cb}	5.6±0.46^{Bb}	5.1±0.26^{Cb}
	6	5.2±0.70^{Ac}	4.3±0.65^{Bc}	0.2±0.27^{Ec}	2.6±0.21^{Dc}	4.6±0.58^{Bc}	5.2±0.33^{Ac}	3.6±0.57^{Cc}
	9	3.9±0.42^{Bd}	3.2±0.49^{Cd}	−0.3±0.19^{Fd}	2.2±0.21^{Ed}	4.1±0.48^{Ad}	4.3±0.60^{Ad}	2.8±0.24^{Dd}
	12	3.7±0.13^{Ad}	3.0±0.48^{Bd}	−0.6±0.29^{Ee}	1.9±0.25^{De}	3.6±0.50^{Ae}	3.9±0.75^{Ae}	2.5±0.45^{Ce}

1)All values are presented as mean±SD (n=5).
2)A-GMeans within a row not followed by the same letter are significantly different ($p<0.05$).
3)a-eMeans within a column not followed by the same letter are significantly different ($p<0.05$).

함량, 플라보노이드 함량, 안토시아닌 함량, DPPH 라디칼 소거능과 색도를 조사하였다. 모든 실험구와 대조구는 발효 진행에 따라 pH는 감소하고 산도는 증가하였다. 가용성 고형분도 증가하였고, 대부분의 실험구가 대조구보다 높았다. 총당은 시간이 지날수록 감소했지만 환원당은 증가하였다. Day 0에서 총당과 환원당은 껍질 첨가군이 대조군보다 높았다. 폴리페놀, 플라보노이드, 안토시아닌 및 DPPH 라디칼 소거능은 발효 진행에 따라 증가하였고, 배를 제외한 모든 첨가군은 비첨가군보다 높게 나타났다. 시간이 지남에 따라 Anthocyanins이 높은 자두와 포도를 제외하고 L값은 증가하였고, 자두와 포도의 a값은 증가하였다($p<0.05$).

Conflict of interests

The authors declare no potential conflicts of interest.

Author contributions

Conceptualization: Lee TY, Yi YH. Investigation: Lee TY, Yi YH. Data curation: Lee TY, Yi YH. Formal analysis: Lee TY, Yi YH. Methodology: Lee TY, Yi YH. Validation: Lee TY, Yi YH. Writing - original draft: Lee TY. Writing - review & editing: Lee TY, Yi YH.

Ethics approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

ORCID

Tae Yeon Lee (First author)
https://orcid.org/0000-0003-2928-0731
Young Hyoun Yi (Corresponding author)
https://orcid.org/0000-0003-2579-0259

References

Abuduaibifu A, Tamer CE. Evaluation of physicochemical and bioaccessibility properties of goji berry kombucha. J Food Process Preserv, 43, e14077 (2019)

Akarca G. Determination of potential antimicrobial activities of some local berries fruits in kombucha tea production. Braz Arch Biol Technol, 64, e21210023 (2022)

Alves MDM, Rosa MDS, Santos PPAD, Paz MFD, Morato PN, Fuzinatto MM. Artisanal beer production and evaluation adding rice flakes and soursop pulp (*Annona muricata* L.). Food Sci Technol, 40, 545-549 (2020)

Aung T, Eun JB. Production and characterization of a novel beverage from laver (*Porphyra dentata*) through fermentation with kombucha consortium. Food Chem, 350, 129274 (2021)

Ayed L, Ben Abid S, Hamdi M. Development of a beverage from red grape juice fermented with the Kombucha consortium. Ann Microbiol, 67, 111-121 (2017)

Battikh H, Bakhrouf A, Ammar E. Antimicrobial effect of kombucha analogues. LWT - Food Sci Technol, 47, 71-77 (2012)

Bhattacharya D, Bhattacharya S, Patra MM, Chakravorty S, Sarkar S, Chakraborty W, Koley H, Gachhui R. Antibacterial activity of polyphenolic fraction of kombucha against enteric bacterial pathogens. Curr Microbiol, 73, 885-896 (2016)

Blanc PJ. Characterization of the tea fungus metabolites. Biotechnol Lett, 18, 139-142 (1996)

Chawla PR, Bajaj IB, Survase SA, Singhal RS. Microbial cellulose: Fermentative production and applications. Food Technol Biotechnol, 47, 107-124 (2009)

Cho MZ. The characteristics of soybean dasik in addition of black pigmented rice. Korean J Food & Nutr, 19, 58-61 (2006)

Chu SC, Chen C. Effects of origins and fermentation time on the antioxidant activities of kombucha. Food Chem, 98, 502-507 (2006)

Coelho RMD, Almeida AL, Amaral RQG, Mota RN, Sousa PHM. Kombucha. Int J Gastron Food Sci, 22, 100272 (2020)

Dimowo CG, Omonigho SE, Oshoma CE, Oyedoh OP. Evaluating the concept of reducing sugar (glucose) and growth in l-asparaginase production using some selected marine actinomycetes. Sci Afr, 22, 105-112 (2021)

Dwiputri MC, Feroniasanti YL. Effect of fermentation to total titrable acids, flavonoid and antioxidant activity of butterfly pea kombucha. J Phys Conf Ser, 1241, 0123014 (2019)

Ehiowemwenguan G, Emoghene AO, Inetianbor JE. Antibacterial and phytochemical analysis of banana fruit peel. IOSR J Pharm, 4, 18-25 (2014)

El-Samahy SK, Youssef KM, Moussa-Ayoub TE. Producing ice cream with concentrated cactus pear pulp: A preliminary study. J Prof Assoc Cactus Dev, 11, 1-12 (2009)

Fawole OA, Makunga NP, Opara UL. Antibacterial, antioxidant and tyrosinase-inhibition activities of pomegranate fruit peel methanolic extract. BMC Complement Altern Med, 12, 1-11 (2012)

Grand View Research. Kombucha Market Size, Share & Trends Analysis Report by Product (Conventional, Hard), by Distribution Channel (On-Trade, Off-Trade), by Region, and Segment Forecasts, 2022-2030 (2022)

Ha SJ. “BTS enjoys drinking” ...kombucha, a big hit, sold for 80 billion won. Available from: https://www.hankyung.com/economy/article/202204262857i. Accessed Apr. 25, 2022.

Hartmann AM, Burleson LE, Holmes AK, Geist CR. Effects of chronic kombucha ingestion on open-field behaviors, longevity, appetitive behaviors, and organs in c57-bl/6 mice: A pilot study. Nutrition, 16, 755-761 (2000)

Hassimotto NMA, Genovese MI, Lajolo FM. Antioxidant activity of dietary fruits, vegetables, and commercial frozen fruit pulps. J Agric Food Chem, 53, 2928-2935 (2005)

Hegazy AE, Ibrahium MI. Antioxidant activities of orange peel extracts. World Appl Sci J, 18, 684-688 (2012)

Hur SJ, Lee SY, Kim YC, Choi I, Kim GB. Effect of fermentation on the antioxidant activity in plant-based foods. Food Chem, 160, 346-356 (2014)

Jayabalan R, Chen PN, Hsieh YS, Prabhakaran K, Pitchai P, Marimuthu S, Periyasamy T, Swaminathan K, Yun SE. Effect of solvent fractions of kombucha tea on viability and invasiveness of cancer cells—characterization of dimethyl 2-(2-hydroxy-2-methoxypropylidine) malonate and vitexin. Indian J Biotechnol, 10, 75-82 (2011)

Jayabalan R, Malbasa RV, Loncar ES, Vitas JS, Sathishkumar M. A review on kombucha tea—microbiology, composition, fermentation, beneficial effects, toxicity, and tea fungus. Compr Rev Food Sci Food Saf, 13, 538-550 (2014)

Jayabalan R, Subathradevi P, Marimuthu S, Sathishkumar M, Swaminathan K. Changes in free-radical scavenging ability of kombucha tea during fermentation. Food Chem, 109, 227-234 (2008)

https://doi.org/10.11002/kjfp.2023.30.2.321

Jeong CH, Lee WJ, Bae SH, Choi SG. Chemical components and antioxidative activity of Korean gold kiwifruit. J Korean Soc Food Sci Nutr, 36, 859-865 (2007)

Jung JG, Yu Y, Kim SK, Lee HR, Choi JU, Lee SH, Ahn H, Chung SK. Quality and nutrition labeling study of domestic fruit (plum). Korean J Food Preserv, 13, 669-674 (2006)

Kaashyap M, Cohen M, Mantri N. Microbial diversity and characteristics of kombucha as revealed by metagenomic and physicochemical analysis. Nutrients, 13, 4446 (2021)

Kaewkod T, Bovonsombut S, Tragoolpua Y. Efficacy of kombucha obtained from green, oolong, and black teas on inhibition of pathogenic bacteria, antioxidation, and toxicity on colorectal cancer cell line. Microorganisms, 7, 700 (2019)

Kandari V, Gupta S. Bioconversion of vegetable and fruit peel wastes in viable product. J Microbiol Biotechnol Res, 2, 308-312 (2012)

Ko HM, Shin SS, Park SS. Biological activities of kombucha by stater culture fermentation with *Gluconacetobacter* spp. J Korean Soc Food Sci and Nutr, 46, 896-902 (2017)

Koschwanez JH, Foster KR, Murray AW. Sucrose utilization in budding yeast as a model for the origin of undifferentiated multicellularity. PLoS Biol, 9, e1001122 (2011)

Kwon YA, Lee KG, Hong KW, Lee SJ. Improving qualities of rice beer using enzymes and amino acids. Food Eng Prog, 16, 151-156 (2012)

Laavanya D, Shirkole S, Balasubramanian P. Current challenges, applications and future perspectives of SCOBY cellulose of Kombucha fermentation. J Clean Prod, 295, 126454 (2021)

Leal JM, Suarez LV, Jayabalan R, Oros JH, Escalante-Aburto A. A review on health benefits of kombucha nutritional compounds and metabolites. CYTA J Food, 16, 390-399 (2018)

Lee MY, Yoo MS, Whang YJ, Jin YJ, Hong MH, Pyo YH. Vitamin C, total polyphenol, flavonoid contents and antioxidant capacity of several fruit peels. Korean J Food Sci Technol, 44, 540-544 (2012)

Loncar ES, Kanuric KG, Malbasa RV, Duric MS, Milanovic SD. Kinetics of saccharose fermentation by kombucha. Chem Ind Chem Eng Q, 20, 345-352 (2014)

Lu X, Wang J, Al-Qadiri HM, Ross CF, Powers JR, Tang J, Rasco BA. Determination of total phenolic content and antioxidant capacity of onion (*Allium cepa*) and shallot (*Allium oschaninii*) using infrared spectroscopy. Food Chem, 129, 637-644 (2011)

Malbasa R, Loncar E, Djuric M. Comparison of the products of kombucha fermentation on sucrose and molasses. Food Chem, 106, 1039-1045 (2008)

Marsh AJ, OSullivan O, Hill C, Ross RP, Cotter PD. Sequence-based analysis of the bacterial and fungal compositions of multiple kombucha (tea fungus) samples. Food Microbiol, 38, 171-178 (2014)

Maurer LH, Cazarin CBB, Quatrin A, Minuzzi NM, Costa EL, Morari J, Velloso LA, Leal RF, Rodrigues E, Bochi VC, Junior MRM, Emanuelli T. Grape peel powder promotes intestinal barrier homeostasis in acute TNBS-colitis: A major role for dietary fiber and fiber-bound polyphenols. Int Food Res J, 123, 425-439 (2019)

Neffe-Skocinska K, Sionek B, Scibisz I, Kolozyn-Krajewska D. Acid contents and the effect of fermentation condition of kombucha tea beverages on physicochemical, microbiological and sensory properties. CYTA J Food, 15, 601-607 (2017)

Omar AF, MatJafri MZ. Principles, methodologies and technologies of fresh fruit quality assurance. Qual Assur Saf of Crops Foods, 5, 257-271 (2013)

Ramteke SP, Kankhare DH, Dhumal VS, Desale RJ, Patil VP. Optimization of mango herbal quarg type cheese with mango pulp and spices. Indian

J Dairy Sci, 73, 181-183 (2020)

Reiss J. Influence of different sugars on the metabolism of the tea fungus. Z Lebensm Unters Forsch, 198, 258-261 (1994)

Ruiz-Torralba A, Guerra-Hernandez EJ, Garcia-Villanova B. Antioxidant capacity, polyphenol content and contribution to dietary intake of 52 fruits sold in Spain. CYTA J Food, 16, 1131-1138 (2018)

Salari M, Khiabani MS, Mokarram RR, Ghanbarzadeh B, Kafil HS. Preparation and characterization of cellulose nanocrystals from bacterial cellulose produced in sugar beet molasses and cheese whey media. Int J Biol Macromol, 122, 280-288 (2019)

Saravanan S, Parimelazhagan T. *In vitro* antioxidant, antimicrobial and anti-diabetic properties of polyphenols of *Passiflora ligularis* Juss. fruit pulp. Food Sci Hum Wellness, 3, 56-64 (2014)

Sengul M, Erkaya T, Sengul M, Yildiz H. The effect of adding sour cherry pulp into yoghurt on the physicochemical properties, phenolic content and antioxidant activity during storage. Int J dairy Technol, 65, 429-436 (2012)

Shahbazi H, Gahruie HH, Golmakani MT, Eskandari MH, Movahedi M. Effect of medicinal plant type and concentration on physicochemical, anti-oxidant, antimicrobial, and sensorial properties of kombucha. Food Sci Nutr, 6, 2568-2577 (2018)

Sharma SB, Nasir A, Prabhu KM, Murthy PS. Antihyperglycemic effect of the fruit-pulp of *Eugenia jambolana* in experimental diabetes mellitus. J Ethnopharmacol, 104, 367-373 (2006)

Shehata WA, Akhtar S, Alam T. Extraction and estimation of anthocyanin content and antioxidant activity of some common fruits. Trends Appl Sci Res, 15, 179-186 (2020)

Shim KH, Kang KS, Choi JS, Seo KI, Moon JS. Isolation and stability of anthocyanin pigments in grape peels. J Korean Soc Food Sci Nutr, 23, 279-286 (1994)

Sievers M, Lanini C, Weber A, Schuler-Schmid U, Teuber M. Microbiology and fermentation balance in a kombucha beverage obtained from a tea fungus fermentation. Syst Appl Microbiol, 18, 590-594 (1995)

Sogi DS, Siddiq M, Greiby I, Dolan KD. Total phenolics, antioxidant activity, and functional properties of 'Tommy Atkins' mango peel and kernel as affected by drying methods. Food Chem, 141, 2649-2655 (2013)

Sreeramulu G, Zhu Y, Knol W. Kombucha fermentation and its antimicrobial activity. J Agric Food Chem, 48, 2589-2594 (2000)

Srihari T, Arunkumar R, Arunakaran J, Satyanarayana U. Downregulation of signalling molecules involved in angiogenesis of prostate cancer cell line (PC-3) by kombucha (lyophilized). Biomed Prev Nutr, 3, 53-58 (2013)

Tanticharakunsiri W, Mangmool S, Wongsariya K, Ochaikul D. Characteristics and upregulation of antioxidant enzymes of kitchen mint and oolong tea kombucha beverages. J Food Biochem, 45, e13574 (2020)

Ting SV, Deszyck EJ. The carbohydrates in the peel of oranges and grapefruit a. J Food Sci, 26, 146-152 (1961)

Ulusoy A, Tamer CE. Determination of suitability of black carrot (*Daucus carota* L. spp. *sativus* var. *atrorubens* Alef.) juice concentrate, cherry laurel (*Prunus laurocerasus*), blackthorn (*Prunus spinosa*) and red raspberry (*Rubus ideaus*) for kombucha beverage production. J Food Meas Charact, 13, 1524-1536 (2019)

Villarreal-Soto SA, Beaufort S, Bouajila J, Souchard JP, Taillandier P. Understanding kombucha tea fermentation: A review. J Food Sci, 83, 580-588 (2018)

Wang H, Cao G, Prior RL. Oxygen radical absorbing capacity of anthocyanins. J Agric Food Chem, 45, 304-309 (1997)

Watawana MI, Jayawardena N, Gunawardhana CB, Waisundara VY. Health, wellness, and safety aspects of the consumption of kombucha. J Chem, 2015 (2015)

Wolfe K, Wu X, Liu RH. Antioxidant activity of apple peels. J Agric Food Chem, 51, 609-614 (2003)

Yoon JY, Noh SJ, Yun SJ, Hong SP, Kim ME. Fruit supply and demand trends and prospects. Agricultural Prospect, 16, 549-642 (2021)

Zahid HF, Ranadheera CS, Fang Z, Ajlouni S. Functional and healthy yogurts fortified with probiotics and fruit peel powders. Fermentation, 8, 469 (2022)

Zhou X, Tan J, Gou Y, Liao Y, Xu F, Li G, Cao J, Yao J, Yea J, Tang N, Chen Z. The biocontrol of postharvest decay of table grape by the application of kombucha during cold storage. Sci Hortic, 253, 134-139 (2019)

Zubaidah E, Afgani CA, Kalsum U, Srianta I, Blanc PJ. Comparison of *in vivo* antidiabetes activity of snake fruit kombucha, black tea kombucha and metformin. Biocatal Agric Biotechnol, 17, 465-469 (2019)