UJMR, Vol. 9 No. 2, December, 2024, pp. 240 - 248 *E-ISSN: 2814 – 1822; P-ISSN: 2616 – 0668*

https://doi.org/10.47430/ujmr.2492.027

Received: 10 September 2024 **Accepted: 02 December 2024**

Development of New Media for the Production of Bacteriocin from *Weissella cibaria* man1

[1*]Samson Baranzan Wayah, [2,3]Koshy Philip, [1]Amos Alvan

[1]Department of Biochemistry, Faculty of Pure and Applied Sciences, Kaduna State University, Nigeria

[2]Institute of Ocean and Earth Sciences, University of Malaya, Malaysia

[3] Institute of Computer Science and Digital Innovation, UCSI University, Malaysia

*Correspondence: +2348161277413,samson.wayah@kasu.edu.ng

ORCID: https://orcid.org/0000-0002-3045-1801

Abstract

Antibiotic resistance is one of the top ten global health challenges. Bacteriocins from lactic acid bacteria are widely considered viable alternatives to antibiotics but suffer a huge commercialization challenge. Thus, this study aimed to investigate the effect of media and pH on bacteriocin production from Weissella cibaria man1. Multiple cost-effective media were developed from cheap, indigenously sourced ingredients, namely, pineapple, watermelon, apple, grape, mango, avocado, carrot, sugar cane, date fruit, tiger nut, cashew nut, groundnut, bean, moringa, baobab, bambara groundnut, soybean, rice, Ziziphus abyssinica, Kunu, egg, beef, fish and cow milk. The formulated media comprised of one-component media, formed from one ingredient and two-component media produced by combining two one-component media in a 1:1 ratio. Bacteriocin production was measured by agar well diffusion assay using Rhizopus stolonifer as an indicator. Results revealed that culture media had significant effect ($p < 0.05$) on bacteriocin production by Weissella cibaria man1. Bacteriocin production was highest in a newly developed media, APC (Apple and Cashew Nut), with a zone of inhibition (ZOI) of 17.9 ± 0.89 mm. Moreover, bacteriocin production in the APC medium was significantly higher and cheaper (cost = ₦14.6/g) than in MRS broth, a commercial medium (ZOI = 15.9 ± 0.52 mm, cost = ₦787.0/g) which was used as the control in this study. Furthermore, bacteriocin production in six (6) additional formulated media namely, DAT (ZOI = 15.5 ± 0.92 mm), BAE (ZOI = 15.6 ± 1.14 mm), DAC (ZOI = 16.5 ± 0.83 mm), CAN (ZOI = 15.9 ± 0.78 mm), PIN (ZOI = 15.7 ± 0.46 mm), and RIG (ZOI = 16.2 ± 1.12 mm) was not significantly different ($p > 0.05$) from that of MRS broth. Since bacteriocin production was highest in the two-component medium, APC, enhancing its yield by exploring the optimal pH was essential. The starting pH of the APC medium significantly influenced bacteriocin synthesis by Weissella cibaria man1 ($p < 0.05$). Furthermore, the optimum level of bacteriocin production in APC medium was observed at pH values of 5 (ZOI = 18.9 mm) and 6 (ZOI = 19.2 mm). These findings will facilitate further optimization of bacteriocin production from Weissella cibaria man1 for potential medicinal applications.

***Keywords:** Bacteriocin, cost-effective media, media formulation, pH, Weissella cibaria*

INTRODUCTION

Infections that are resistant to antibiotics cause more deaths and illnesses, which is why the World Health Organization has listed antibiotic resistance as one of the top ten global health problems (Sauerborn *et al*., 2024). The antibiotic development pipeline has relied nearly solely on variants of current chemical scaffolds, which has halted the discovery of new classes of antibiotics that can overcome resistance for decades. New therapeutic solutions are required because this strategy has not been able to keep up with the emergence of antibiotic resistance (MacNair *et al*., 2024). Following the COVID-19 pandemic, there has been a growing recognition of probiotic-derived bacteriocins as effective substitutes for antibiotics (Bisht *et al*., 2024).

Bacteriocins are soluble peptides synthesized by the ribosome. They efficiently suppress their targeted microorganisms by employing distinctive mechanisms that hinder the development of resistance, and they are generally considered safe for human ingestion (MacNair *et al*., 2024).

Weissella cibaria is widely considered to possess huge probiotic potential due to its ability to produce bacteriocins (Deviyanti *et al.*, 2023; Singh *et al.*, 2024). Bacteriocin-producing strains of *Weissella cibaria* include *Weissella cibaria* 110, *Weissella cibaria* FMF4B16, *Weissella cibaria* N23, *Weissella cibaria* KMITL-QU 21, and *Weissella cibaria* man1 (Singh *et al.*, 2024; Wayah *et al.*, 2024).

Low yield is one of the bottlenecks of commercialization of bacteriocins (Sharma & Yadav, 2022). Improving our knowledge of the factors that influence bacteriocin biosynthesis is crucial for increasing their productivity. Carbon and nitrogen supplies and fermentation conditions including pHave been found to influence bacteriocin synthesis (Garmasheva & Oleschenko, 2023). Expensive commercial laboratory media like DeMan Rogosa Sharpe (MRS), Brain-heart infusion (BHI), and M17 have been used in the majority of investigations on bacteriocin production (Goh & Philip, 2015). Therefore, developing cost-effective media for bacteriocin production will greatly facilitate commercialization. Subsequently, this study was embarked upon to develop media for producing bacteriocin from *Weissella cibaria* man1 using cheap raw materials.

MATERIALS AND METHODS

Microbial strains and growth media

Bacteriocin-producing *Weissella cibaria* man1 was isolated from ripe *Mangifera indica* (Mango) as described in our previous study (Wayah *et al.*, 2024) and deposited in the culture collection of the Department of Biotechnology, Kaduna State University. *Weissella cibaria* man1 was cultured on De Man Rogosa Sharpe (MRS) agar (Merck, Darmstadt, Germany). *Rhizopus stolonifer* was obtained from the Department of Microbiology, Kaduna State University, and maintained on Sabouraud Dextrose Agar (Merck, Darmstadt, Germany).

Development of new media for bacteriocin production

Rationale for selection and variation in quantities of ingredients used for media development

Bacteriocin-producing bacteria require carbon and nitrogen sources for growth and bacteriocin production (Parlindungan *et al.*, 2021). Therefore, raw materials that contain carbohydrates, proteins or both nutrients were selected for media preparation. The quantity of each raw material used for media preparation was chosen based on the amount needed to obtain an adequate volume of the media.

Development of one-component media

One-component media are those formulated from one indigenously sourced ingredient, which included pineapple, watermelon, apple, grape, mango, avocado, carrot, sugar cane, date fruit, tiger nut, cashew nut, groundnut, bean, *Moringa oleifera*, *Adansonia digitata* (Baobab), bambara groundnut, soybean, rice, *Ziziphus abyssinica*, Kunu, egg, beef, fish and cow milk (Hayek *et al.*, 2019).

Pineapple, watermelon, apple and grape

In order to obtain an adequate quantity of extract for use as a growth medium, 1 kg of edible parts of pineapple fruit were weighed, cut into smaller pieces, and blended. The juice was extracted by sieving to form the pineapple (PIN) medium. The same approach was employed to produce watermelon (WAT), apple (APP), and grape (GRJ) media, respectively.

Mango, avocado, and carrot

Mango (500 g) was weighed, cut into small pieces, and put into a blender. Thereafter, 250 mL of distilled water was added, blended to homogenize, and sieved to obtain mango (MAN) medium. The same approach produced avocado (AVO) and carrot (CAR) media.

Sugar Cane

Peeled sugar cane was weighed (1 kg) and cut into small pieces, after which a juice extractor was used to obtain the sugarcane (SUC) medium.

Date fruit, tiger nut, cashew nut, groundnut and bean

The edible part of date fruits (500 g) was put into a beaker, and 250 mL distilled water was added, after which it was allowed to soak for 7 hours. The mixture was then added to a blender and homogenized. The dates (DAT) medium was obtained by sieving. Cashew nut (CAN) medium, bean (BEM) medium, Tiger nut (TI) extract, and groundnut (GR) extract were prepared by the same procedure.

Moringa oleifera

Moringa leaves (500 g) were mixed with 150 mL of water and blended, after which it was sieved to obtain moringa (MOE) medium.

Adansonia digitata (Baobab)

The seeds were removed, and the remains were pounded using a mortar. The powder (500 g) was mixed with 200 mL distilled water and sieved to obtain a baobab (BAE) medium.

Bambara groundnut

Bambara groundnut (500 g) was ground into powder, and 200 mL distilled water was added.

The mixture was sieved to obtain bambara groundnut (BAM) medium.

Soybean and rice
Soybean was ground into powder, after which 500 g was mixed with 250 mL of distilled water and blended to homogenize. The mixture was sieved to obtain soybean (SOB) medium. Rice extract (RI) was obtained by the same method.

Ziziphus abyssinica
The edible part of the fruit was ground into powder, and 500 g was mixed with 250 mL of distilled water. After homogenization, it was sieved to obtain *Ziziphus abyssinica* (MGE) medium.

Kunu
Kunu is a locally made indigenous drink. This drink comprised of guinea corn, millet, sweet potato, ginger, cloves, and water. About 200 mL of the kunu medium (KNZ) was purchased and used for this study.

Egg
The egg was boiled and 500 g of the edible part was mixed with 200 mL of distilled water and blended. A sieve was used to sieve the mixture, resulting in the egg (EGG) medium.

Beef, fish and cow milk
The beef was boiled without any seasoning, and then 500 g was cut into small pieces and mixed with 200 mL of distilled water. The mixture was sieved to obtain beef (BEE) medium. Fish (FIE) medium was prepared by the same procedure. Fresh cow milk (200 mL) was purchased and used as a cowmilk (COM) medium.

Development of two-component media
Two-component media are those formulated by combining two one-component media in a 1:1 ratio. These media are as follows: APC (APP + CAN), COS (COM +SUC), BES (BEE + SUC), EGP (EGG + PIN), WBM (WAT + BEM), GRS (GRJ+SOB), DAC (DAT + COM), BAC (BEA + COM), TIG (TI + GR), RIG (RI + GR), MAS (MAN + SOB), WBM (WAT + BEM), GRS (GRJ + SOB), CAC (CAR + COM), KUS (KNZ + SUC), PIC (PIN + COM), and COS (COM + SUC) (Hayek *et al*., 2019).

Preparation of inoculum
Cell pellets of a 24-hour-old *Weissella cibaria* man1 MRS broth culture were obtained by centrifuging (2000×g for 10 minutes), resuspended in 0.85% saline solution, and washed twice by centrifuging using the same conditions, using a fresh 0.85% saline solution for each wash. T cell pellet was resuspended in 0.85% saline solution, and the optical density (OD_{600} nm) was adjusted to 0.1 (Wayah & Philip, 2018).

Effect of media on growth and bacteriocin production by *Weissella cibaria* man1
In order to determine the effect of media on bacteriocin production, the inoculum was added (10% v/v) to all the sterilized developed liquid media and MRS broth (Control), after which all inoculated media were incubated at 37^0C for 24 hours. Growth of *Weissella cibaria* man1 was measured by subculturing the 10-fold serially diluted cultures into their respective solid new media (produced by adding 1.5% w/v agar to the newly developed liquid media) and MRS agar followed by incubation at 37^0C for 24 hours. Bacteriocin production was determined by agar well diffusion assay using *Rhizopus stolonifer* as the indicator of bacteriocin production. Briefly, the 24-hour broth cultures were centrifuged at 10,000 x g for 20 minutes to collect the supernatant filtered using 0.2 µm membrane to obtain cell-free supernatant (CFS). The indicator of bacteriocin production (*Rhizopus stolonifer*) was cultured in Sabouraud Dextrose Broth at 30°C for 24 hours. The cultures were centrifuged at 5000 rpm for 5 minutes to collect the cell pellets, which were then resuspended in 0.85% saline solution, and the optical density at 600 nm was adjusted to 0.1. Afterward, Sabouraud Dextrose Agar plates containing 25 mL of the media (enriched with 0.1% $CaCO_3$ to counteract the acidity caused by organic acids) were seeded with the resuspended *Rhizopus stolonifer* and wells (6 mm in diameter) were made. To these wells, 50 µL of CFS was added. Uninoculated broth without bacteriocin was used as the negative control. Inoculated plates were incubated at 30°C for 24 hours, and zones of inhibition were measured (Wayah & Philip, 2018).

Effect of pH on growth and bacteriocin production by *Weissella cibaria* man1

To examine the impact of pH on bacteriocin production, the APC medium was modified to various pH levels (4, 5, 6, 7, and 8) before being autoclaved. Following autoclaving and cooling to ambient temperature, each medium was inoculated with 10% (v/v) of the inoculum and incubated at 37^{0}C for 24 hours, after which an agar well diffusion assay was carried out as described above (Wayah *et al.*, 2022).

Data analysis

Experiments were done in three (3) replications from which mean values and standard deviations were calculated. IBM SPSS Software (version 29) was used to conduct a one-way analysis of variance to compare mean values for significant differences or lack thereof at 95% confidence level.

RESULTS

Effect of media on growth and bacteriocin production by *Weissella cibaria* man1

Culture media had a significant effect ($p < 0.05$) on the growth of *Weissella cibaria* man1 at 95% confidence level. *Weissella cibaria* man1 had the lowest growth level in GRJ medium (Log_{10} CFU/ml = 6.5) while the highest growth was observed in BES (Log_{10} CFU/ml = 18.8), MGE (Log_{10} CFU/ml = 19.7), WBM (Log_{10} CFU/ml = 19.1), GRS (Log_{10} CFU/ml = 18.8), and COM medium (Log_{10} CFU/ml = 18.9) (Table 1 and Table 2). Culture media also had a significant effect ($p < 0.05$) on bacteriocin production from *Weissella cibaria* man1 (Table 1, Table 2 and Figure 1). Bacteriocin production from Weissella cibaria man1 was observed to be maximum in APC, with a zone of inhibition (ZOI) of 17.9 mm (Table 2). Further, bacteriocin production in DAT (ZOI =15.5 mm), BAE (ZOI =15.6 mm), DAC (ZOI =16.5 mm), CAN (ZOI =15.9 mm), PIN (ZOI = 15.7 mm), RIG (ZOI = 16.2 mm) was not significantly different ($p > 0.05$) from MRS broth (ZOI = 15.9). Substantial level of bacteriocin was also observed in BEM (ZOI = 14.0 mm), APP (ZOI = 14.7 mm), GRJ (ZOI = 14.5 mm), WBM (ZOI = 14.5 mm), and BAM (ZOI = 14.4 mm) (Tables 1 and Table 2).

Table 1: Effect of newly developed one-component media on growth and bacteriocin production by *Weissella cibaria* man1

Media	Growth (Log_{10} CFU/ml)	Zone of inhibition (mm)
WAT	8.9 ± 0.53^g	12.5 ± 0.75^c
BEM	13.4 ± 1.21^d	14.0 ± 0.63^b
DAT	17.2 ± 1.56^b	15.5 ± 0.92^a
BAE	14.8 ± 0.86^d	15.6 ± 1.14^a
APP	8.9 ± 0.75^g	14.7 ± 0.18^b
GRJ	6.2 ± 0.77^i	14.5 ± 0.53^b
KNZ	17.8 ± 0.94^b	10.8 ± 0.36^d
AVO	16.4 ± 2.11^c	7.8 ± 0.27^g
CAN	13.7 ± 2.21^d	15.9 ± 0.78^a
BAM	17.1 ± 0.72^b	14.4 ± 0.92^b
COM	18.9 ± 0.41^a	11.8 ± 0.07^c
PIN	13.6 ± 0.56^d	15.7 ± 0.46^a
BEE	12.5 ± 1.83^e	9.0 ± 0.31^e
SOB	17.8 ± 0.71^b	10.5 ± 0.42^d
FIE	7.9 ± 0.19^h	7.5 ± 0.08^g
CAR	8.7 ± 0.76^g	8.9 ± 0.18^f
SUC	8.6 ± 0.92^g	10.8 ± 0.34^d
MAN	17.1 ± 0.92^b	7.9 ± 0.19^g
MGE	19.7 ± 1.43^a	9.9 ± 0.51^e
MOE	12.7 ± 1.23^e	10.5 ± 0.28^d
EGG	16.3 ± 0.78^c	0.0 ± 0.00^i
Control (MRS broth)	10.2 ± 0.59^f	15.9 ± 0.52^a

Values are means of triplicate measurements ± standard deviation, mean values that differ significantly at 95% confidence level were assigned different letters

Table 2: Effect of newly developed two-component media on growth and bacteriocin production by *Weissella cibaria* man1

Media	Growth (Log_{10} CFU/ml)	Zone of inhibition (mm)
EGP	14.6 ± 0.34^{c}	11.1 ± 0.29^{d}
BES	18.8 ± 1.54^{a}	11.6 ± 0.74^{d}
APC	8.8 ± 0.98^{f}	17.9 ± 0.89^{a}
WBM	19.1 ± 1.13^{a}	14.5 ± 0.72^{c}
GRS	18.8 ± 1.82^{a}	8.5 ± 0.62^{g}
DAC	11.2 ± 1.92^{d}	16.5 ± 0.83^{b}
BAC	12.1 ± 1.66^{d}	10.2 ± 0.93^{e}
TIG	7.7 ± 0.49^{g}	10.5 ± 0.87^{e}
CAC	9.9 ± 1.11^{e}	11.2 ± 0.26^{d}
KUS	10.2 ± 1.23^{e}	0.0 ± 0.00^{i}
PIC	17.9 ± 1.43^{b}	9.2 ± 0.09^{f}
COS	18.1 ± 0.92^{b}	0.0 ± 0.00^{i}
RIG	12.3 ± 1.76^{d}	16.2 ± 1.12^{b}
MAS	9.6 ± 0.33^{e}	8.5 ± 0.86^{g}
Control (MRS broth)	10.2 ± 0.59^{e}	15.9 ± 0.52^{b}

Values are means of triplicate measurements ± standard deviation, mean values that differ significantly at 95% confidence level were assigned different letters

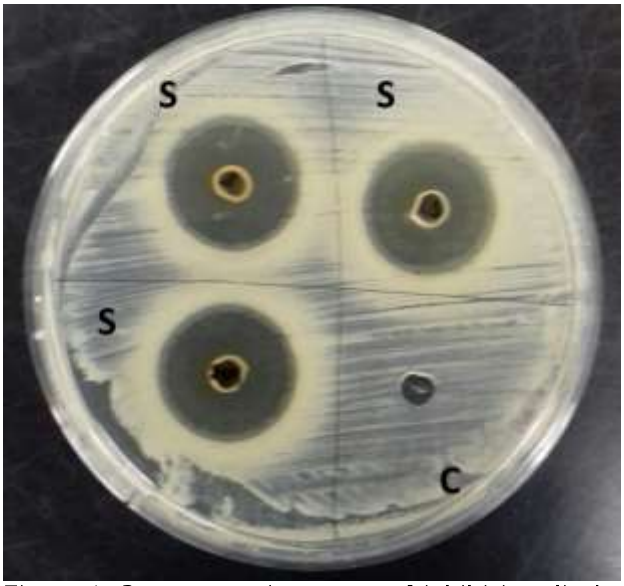

Figure 1: Representative zones of inhibition displayed by bacteriocin from *Weissella cibaria* man1. S: sample, C: control

Of all the ingredients used for developing the one-component media, MGE (*Ziziphus abyssinica*) was the cheapest ₦0.6/g while the most expensive (₦13.2/g) was CAN (Cashew nut) (Table 3). Among the two-component media formulated, APC medium (Apple and Cashew Nut) was the most expensive (₦14.6/g), while the cheapest was MAS (mango and soybean) which cost ₦2.0/g (Table 4). However, all formulated media, comprising of one-component and two-component media, were cheaper than commercial media used for bacteriocin production from *Weissella cibaria,* namely, MRS broth (₦787.0/g), Brain-heart infusion (₦562.7/g), and M17 (₦954.3/g) (Table 3 and Table 4).

Table 3: Cost of developing one-component media compared to commercial media.

Media	Cost (₦/g)
WAT	1.0
BEM	2.6
DAT	8.6
BAE	5.0
APP	1.4
GRJ	7.6
KNZ	5.2
AVO	6.3
CAN	13.2
BAM	10.3
COM	2.5
PIN	2.1
BEE	4.5
SOB	1.2
FIE	5.5
CAR	1.1
SUC	2.3
MAN	0.8
MGE	0.6
MOE	1.8
EGG	2.6
MRS broth (commercial)	787.0
Brain-heart infusion (commercial)	562.7
M17 (commercial)	954.3

Table 4: Cost of developing two-component media compared to commercial media.

Media	Cost (₦/g)
EGP (EGG + PIN)	4.7
BES (BEE + SUC)	6.8
APC (APP + CAN)	14.6
WBM (WAT + BEM)	3.6
GRS (GRJ+SOB)	8.8
DAC (DAT + COM)	11.1
BAC (BAE + COM),	7.5
GRT (TI + GR)	4.0
CAC (CAR + COM)	3.6
KUS (KNZ + SUC)	7.5
PIC (PIN + COM)	4.6
COS (COM + SUC)	4.8
RIG (RI + GR)	5.0
MAS (MAN + SOB)	2.0
MRS broth (commercial)	787.0
Brain-heart infusion (commercial)	562.7
M17 (commercial)	954.3

Effect of pH on growth and bacteriocin production by *Weissella cibaria* man1

Since the maximum bacteriocin production occurred in the APC medium, it was imperative to further improve the yield of the bacteriocin by investigating the optimum pH. The initial pH of the culture medium was found to significantly ($p < 0.05$) influence bacteriocin production from *Weissella cibaria* man1. Bacteriocin production was maximum at pH values of 5 (ZOI = 18.9 mm) and 6 (ZOI = 19.2 mm) (Figure 2). Next to these was the unadjusted pH value (ZOI = 17.4 mm). The lowest level of bacteriocin production was seen in the APC medium with an initial pH value of 8 (ZOI = 12.5 mm).

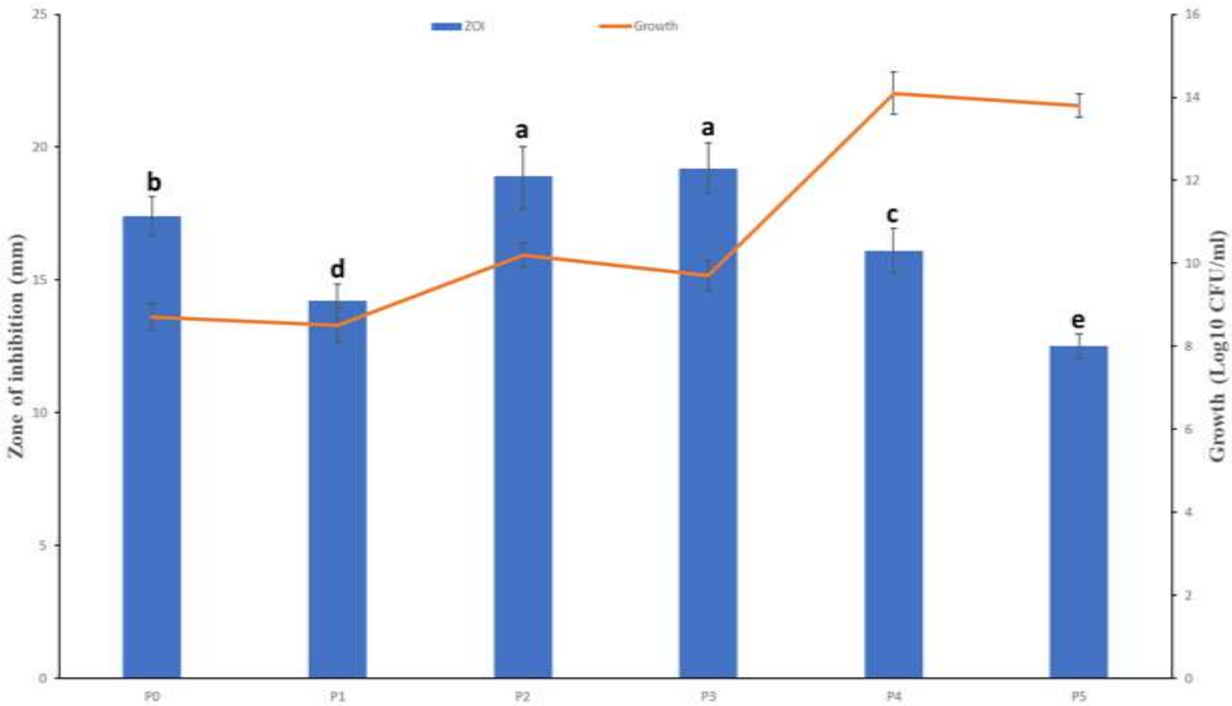

Figure 2: Effect of pH on growth and bacteriocin production by *Weissella cibaria* man1. **P0** (unadjusted pH, control), **P1** (pH 4), **P2** (pH 5), **P3** (pH 6), **P4** (pH 7), **P5** (pH 8). Mean values that differ significantly at 95% confidence level were assigned different letters

DISCUSSION

All newly developed media except EGG (egg medium), KUS (Kunu medium and sugarcane), and COS (cowmilk and sugarcane) were observed to support the growth and production of bacteriocin by *Weissella cibaria* man1. Interestingly, bacteriocin production in APC medium (Apple and Cashew Nut) was significantly higher than in MRS broth, a commercial medium. This could be attributed to adequate levels of carbon, nitrogen, vitamins, and micronutrients in the formulated media (Abbasiliasi *et al.*, 2017). Additionally, bacteriocin production by *Weissella cibaria* man1 in DAT, BAE, DAC, CAN, PIN, RIG was not significantly different from MRS broth. Given the high cost of commercial media for bacteriocin production, such as MRS broth, this research has identified cheap media for producing bacteriocins. Other new media that enhanced the production of substantial levels of bacteriocin include BEM, APP, GRJ, WBM, and BAM. The growth and bacteriocin synthesis in *Lactiplantibacillus plantarum* B21 were found to be considerably influenced by the nitrogen and Tween sources in the culture medium (Parlindungan *et al.*, 2021). Lack of bacteriocin production in KUS, EGG, and COS media could be due to the fact that their constituents suppressed the synthesis and effectiveness of bacteriocins, therefore attenuating the antagonistic effects of the bacteriocin on *Rhizopus stolonifer*. Media affected the production of bacteriocin from Pediococcus pentosaceus ST65ACC (Oliveira *et al.*, 2024). Overall, it was observed that the high growth of *Weissella cibaria man*1 did not translate into high bacteriocin production. Bacteriocin production has been reported to be associated with stress (Kang *et al.*, 2022; Zhao *et al.*, 2021).

Although APC demonstrates a higher level of bacteriocin production from *Weissella cibaria* man1, it is still considerably more cost-effective at ₦14.6/g in contrast to MRS broth, which is priced at ₦787.0/g. This highlights the economic advantages of utilizing locally sourced ingredients for media formulation. Alternative one-component media, including MAN (mango, ₦0.8/g), CAR (carrot, ₦1.1/g), and WAT (watermelon, ₦1.0/g), present more economical choices, although they did not reach the same levels of bacteriocin production as APC. Two-component media like MAS (mango + soybean at ₦2.0/g) and WBM (watermelon + bean at ₦3.6/g) are still very cost-effective, yet they did not surpass the performance of APC. The findings underline the need for nutrient synergy in media development, in which a mix of elements might improve bacterial production above what is possible with single components or costly commercial media (Townsend *et al.*, 2023). APC's higher bacteriocin yield shows that well-chosen local components can beat accepted commercial formulations such as MRS, therefore offering a sustainable and easily available substitute for mass manufacturing.

Since the highest level of bacteriocin production from *Weissella cibaria* man1 occurred in APC medium it was important to further increase its yield by investigating the optimum pH. The initial pH of the culture medium significantly ($p < 0.05$) affected bacteriocin production from *Weissella cibaria* man1. Specifically, bacteriocin production was maximum at pH values of 5 and 6. Bacteriocin production from *Lactobacillus acidophilus* MS1 was influenced by the initial pH of the culture medium. Further, these authors established an optimum pH value of 6 for this bacteriocin producer (Salman *et al.*, 2020). Another study revealed that the growth of *Lactobacillus curvatus* (Arla-10), *Enterococcus faecium (*JFR-1), *Lactobacillus paracasei* subsp. *paracasei* (JFR-5), and *Streptococcus thermophilus* were significantly influenced by the starting pH of the culture media. The optimal pH range for these bacteria was determined to be between 6.2 and 8.5 (Yang *et al.*, 2018). The correlation between bacteriocin synthesis and pH implies that the expression of the biosynthetic genes may be controlled by pH, as previously established for many gene classes (Yang *et al.*, 2018) Another study observed that pH of culture medium significantly influenced bacteriocin production from *Lactobacillus plantarum*. It reported that optimum bacteriocin production occurred at pH values of 7 and 8 (Veettil & Chitra, 2022). The influence of pH on the synthesis of bacteriocins from *Weissella cibaria* man1 may be ascribed to quite many parameters. These factors encompass its impact on the bacteriocin producer's proliferation, the bacteriocin's efficacy and solubility, and the bacteriocin's immobilization onto the producer's cell wall.

CONCLUSION

Several cost-effective bacteriocin production media were developed. Bacteriocin production by *Weissella cibaria* man1 was found to the influenced by culture media. APC, one of the newly formulated media, had the highest level of bacteriocin production. This medium produced bacteriocin at a level significantly higher than the commercial medium, MRS broth. While APC shows a greater capacity for bacteriocin production from *Weissella cibaria* man1, it remains significantly more economical at ₦14.6/g compared to MRS broth, which costs ₦787.0/g. Furthermore, 6 additional, newly developed media, namely, DAT, BAE, DAC, CAN, PIN, and RIG had bacteriocin levels as much as that of MRS broth. Moreover, bacteriocin production by *Weissella cibaria* man1 was significantly affected by the initial pH of the APC culture medium. Furthermore, an optimum level of bacteriocin was achieved at pH values of 5 and 6. These discoveries will greatly facilitate industrial production of bacteriocin from bacteriocinogenic lactic acid bacteria for medical applications.

Conflict of interest

The authors declare that there is no conflict of interest.

REFERENCES

Abbasiliasi, S., Tan, J. S., Tengku Ibrahim, T. A., Bashokouh, F., Ramakrishnan, N. R., Mustafa, S., & Ariff, A. B. (2017). Fermentation factors influencing the production of bacteriocins by lactic acid bacteria: A review. *RSC Advances*, *7*, 29395–29420. **[Crossref]**

Bisht, V., Das, B., & Navani, N. K. (2024). Bacteriocins sourced from traditional fermented foods for ensuring food safety: The microbial guards. *Journal of the Science of Food and Agriculture*. **[Crossref]**

Deviyanti, S., Dewi, K. K., & Widyastuti, R. (2023). Effectiveness of using *Weissella cibaria* CMU bacteria as oral probiotics for halitosis therapy: A scoping review. *International Journal of Clinical Science and Medical Research, 3*, 143-149. [Crossref]

Garmasheva, I. L., & Oleschenko, L. T. (2023). Screening of bacteriocin-producing dairy *Enterococcus* strains using low-cost culture media. *Frontiers in Microbiology, 14*, 1168835. [Crossref]

Goh, H. F., & Philip, K. (2015). Purification and characterization of bacteriocin produced by *Weissella confusa* A3 of dairy origin. *PLoS One, 10*, e0140434. [Crossref]

Hayek, S. A., Gyawali, R., Aljaloud, S. O., Krastanov, A., & Ibrahim, S. A. (2019). Cultivation media for lactic acid bacteria used in dairy products. *Journal of Dairy Research, 86*, 490-502. [Crossref]

Kang, J., Zhou, X., Zhang, W., Pei, F., & Ge, J. (2022). Transcriptomic analysis of bacteriocin synthesis and stress response in *Lactobacillus paracasei* HD1 under acetic acid stress. *LWT, 154*, 112897. [Crossref]

MacNair, C. R., Rutherford, S. T., & Tan, M. W. (2024). Alternative therapeutic strategies to treat antibiotic-resistant pathogens. *Nature Reviews Microbiology, 22*, 262-275. [Crossref]

Oliveira, F. S., da Silva Rodrigues, R., Caviccholi, V. Q., de Carvalho, A. F., & Nero, L. A. (2024). Influence of different culture media on the antimicrobial activity of *Pediococcus pentosaceus* ST65ACC against *Listeria monocytogenes*. *Brazilian Journal of Microbiology*, 1-7. [Crossref]

Parlindungan, E., Dekiwadia, C., & Jones, O. A. H. (2021). Factors that influence growth and bacteriocin production in *Lactiplantibacillus plantarum* B21. *Process Biochemistry, 107*, 18-26. [Crossref]

Salman, M., Shahid, M., Sahar, T., Naheed, S., Mahmood-ur, R., Arif, M., Iqbal, M. J., & Nazir, A. (2020). Development of regression model for bacteriocin production from local isolate of *Lactobacillus acidophilus* MS1 using Box-Behnken design. *Biocatalysis and Agricultural Biotechnology, 24*, 101542. [Crossref]

Sauerborn, E., Corredor, N. C., Reska, T., Perlas, A., Vargas da Fonseca Atum, S., Goldman, N., Wantia, N., da Costa, C. P., Foster-Nyarko, E., & Urban, L. (2024). Detection of hidden antibiotic resistance through real-time genomics. *Nature Communications, 15*, 1-8. [Crossref]

Sharma, P., & Yadav, M. (2022). Enhancing antibacterial properties of bacteriocins using combination therapy. *Journal of Applied Biology & Biotechnology*. [Crossref]

Singh, J. K., Devi, P. B., Reddy, G. B., Jaiswal, A. K., Kavitake, D., & Shetty, P. H. (2024). Biosynthesis, classification, properties, and applications of *Weissella* bacteriocins. *Frontiers in Microbiology, 15*, 1406904. [Crossref]

Townsend, J. R., Kirby, T. O., Sapp, P. A., Gonzalez, A. M., Marshall, T. M., & Esposito, R. (2023). Nutrient synergy: Definition, evidence, and future directions. *Frontiers in Nutrition, 10*, 1279925. [Crossref]

Veettil, V. N., & Chitra, A. V. (2022). Optimization of bacteriocin production by *Lactobacillus plantarum* using Response Surface Methodology. *Cellular and Molecular Biology, 68*, 105-110. [Crossref]

Wayah, S. B., Abubakar, S., Saleh, J., Alvan, A., & Yado, S. (2024). Isolation and molecular identification of indigenous bacteriocin-producing *Weissella cibaria*. *FUDMA Journal of Sciences, 8*, 300-306. [Crossref]

Wayah, S. B., & Philip, K. (2018). Characterization, yield optimization, scale-up, and biopreservative potential of fermencin SA715, a novel bacteriocin from *Lactobacillus fermentum* GA715 of goat milk origin. *Microbial Cell Factories, 17*, 1-18. [Crossref]

Wayah, S. B., Philip, K., Auta, R., Waziri, P. M., & Yahaya, G. (2022). Salivaricin mmaye1 production is enhanced in a new medium and acts synergistically with pentocin MQ1. *FUDMA Journal of Sciences, 6*, 214-221. [Crossref]

Yang, E., Fan, L., Yan, J., Jiang, Y., Doucette, C., Fillmore, S., & Walker, B. (2018). Influence of culture media, pH, and temperature on growth and bacteriocin production of bacteriocinogenic lactic acid bacteria. *AMB Express, 8*, 1-14. [Crossref]

Zhao, L., Zhao, P., Shang, J., & Meng, X. (2021). Transcriptome analysis of the molecular mechanism of bacteriocin synthesis in *Lactobacillus plantarum* KLDS1-0391 under nanoparticle NaCl stress. *Journal of Biomedical Nanotechnology, 17*, 369-381. [Crossref]