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RESEARCH ARTICLE

Vegetable wastes as a bio-additive for low-salt preservation of raw goat skin: An attempt to reduce salinity in leather manufacture

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Abstract

Preservation or curing of hides/skins is performed as the primary step of leather processing to conserve them from putrefaction. Normally preservation is carried out using common salt (NaCl), which is discharged in the soak liquor contributing to ~ 70%, of total dissolved solids (TDS) load of entire leather manufacturing. In an attempt to reduce the TDS and chlorides, phyto-based preservation using garlic peel (*Allium sativum*) and white onion peel (*Allium cepa*) was carried out. Different concentrations of salt in combination with garlic peel and white onion peel were applied on freshly flayed goat skins based on its green weight and compared to control (40% salt). Sensory evaluation of the preserved skin was done by assessing different parameters like hair slip, putrefaction and odour. Estimation of hydroxyproline (HP) release, moisture content and microbial load were carried out at regular intervals. Skins that remained in good condition for 14 days were further processed into leather and properties were examined which were found comparable to the conventionally cured skins. Hence, this cleaner curing technique helps in reducing the TDS and chlorides in the effluent, thus controlling the pollution caused by tanneries through sustainable leather processing.

Keywords *Allium cepa* · *Allium sativum* · Curing · Hydrothermal stability · Leather processing · Pollution reduction · Raw skin/hide

Introduction

Converting raw hides/skins into leather is a traditional craft that has transformed into a huge industry in the past decades. During preservation process, the hides/skins undergo a temporary and reversible phase of providing transitory stability by increasing the shelf life. Thus, curing though not one of the critical junctures in leather making has become the foremost and important step in the supply chain. The curing of raw hides/skins is popularly done by applying 40–50% of salt (based on fresh weight of the hide/ skin) due to its easy availability and economic feasibility. However, this generates considerable amount of pollution in terms of TDS and chlorides, contributing to ~ 70% of TDS load from leather manufacturing. Chloride concentration in conventiona1 tannery wastewater is about 9000 ppm which represents a considerable problem for biological treatment plants (Cassano et al. 2001). However, preservation of raw hides and skins is also necessary since they are highly putrescible owing to the presence of about 30–35% protein and 60–65% moisture (Vijayalakshmi et al. 2009). Hence, there is a pressing need to search for alternative to salt curing keeping in view the associated environmental and health issues. Since the past decade, many plant-based formulations (Preethi et al. 2006; Sivabalan and Jayanthi 2009; Vijayalakshmi et al. 2009; Ahmed et al. 2015; Tamil Selvi et al. 2015, 2020; Vinodhkumar et al. 2016; Suparno et al. 2017; Hashem et al. 2018, 2021; Uddin et al. 2019) have been exploited for the short-term preservation of raw hides/skins. In the present study for the first time, we report the preservation of raw goat skins using waste peels of garlic and white onion.

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Garlic and onions are widely used around the world for their pungent flavour as a seasoning or condiment. Garlic cloves are used for consumption (raw or cooked) or for medicinal purposes and clinical investigations suggest many favourable effects. These effects have been largely attributed to reduction of risk factors for cardiovascular diseases, reduction of cancer risk, antioxidant effect, antimicrobial effect and hepatoprotection (Colín-González et al. 2012: Bayan et al. 2014). The pungent fractions of garlic are mostly sulphur-containing moieties while its two chemical groups have marked effect on human health. These are flavonoids and ALK (EN)-based cysteine sulfoxides (ACSO's). On the other hand, onions possess strong characteristic aroma and flavours, which have made them important ingredients in food. Compounds in onions have been reported with a range of health benefits, including anticancer properties, antiplatelet activity, antithrombotic activity, antiasthmatic activity and hypocholesterolemic effects. It has been reported that bioactive compounds are present in every part of onion bulb (Benítez et al. 2011; Suleria et al. 2015).

Among vegetables, garlic and onion production occupies a leading position worldwide due to their wide usage in various sectors of the food industry. During food processing, the outer scales and roots of garlic and onion bulb are removed, generally regarded as waste, which is a serious problem especially when it represents loss of valuable source of nutrients and phytochemicals. The amount of waste from peeling garlic is 16–20% of feedstock weight, which is approximately 2.3–2.9 million tons/year, whereas the amount of onion peel waste ranges from 5.0–9.0 to 21.6–29.9% of feedstock weight depending on the size of the bulbs which is approximately 3.66–21.9 million tons/year (Kotenkova and Kupaeva 2019). The food industry produces a huge quantity of these wastes which may amount to nuisance to the environment if not properly discharged. Hence, the present study aims to investigate the beneficial properties of these wastes and put them to good use. The present investigation is the first of its kind, where the objective to the study was to utilize the discarded garlic and white onion peel for preserving raw goat skins and successfully converting to leather with properties comparable to traditionally preserved skins.

Materials and methods

Preparation of raw material and its extract

The garlic and onion peels were collected from the local market. Peels were washed with tap water followed by sterilized distilled water, and dried at room temperature for 3 days. These thoroughly dried peels were ground into powder with the help of electric blender. The powder was transferred into closed containers and used as raw material for further use. The methanolic extract of these was prepared using 5 g of peel powder in 200 mL of 70% methanol by Soxhlet extraction method. The solution was concentrated using a rotary evaporator and stored in amber bottles for further use. The extracts were subjected for the detection of phytochemicals according to standard method (Abdulkadir et al. 2018).

Fourier Transform Infrared (FT-IR) analysis

The methanolic extracts of garlic and onion peels were subjected to FT-IR analysis to study for their functional group. The FT-IR spectra of the samples were recorded using a 2000 Perkin-Elmer spectrophotometer, which was first calibrated for background scanning signal against a control sample of pure methanol.

Determination of antibacterial and antioxidant activity

Antibacterial study was performed for the methanolic extract of above-mentioned peels against prominent skin-degrading bacteria (*Bacillus subtilis* and *Staphylococcus aureus*) by agar well diffusion method. For this, two different concentrations of the extracts (500 µg and 1000 µg) were dissolved in 1 mL of dimethyl sulphoxide (DMSO). The experiment was carried out by spreading the young culture of test bacteria using sterile cotton swab on Mueller–Hinton (MH) agar plates. Wells were then bored and 50 µL of the extracts was added to the wells in individual plate. The plates were incubated for 24–48 h at 35 ± 2 °C. The diameter of the zone of clearance, if any, was measured.

The free radical scavenging capacity of the peel extracts was determined using the 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) (Onyeoziri et al. 2016). Briefly, freshly prepared DPPH solution in 0.5 mL methanol was added to 3 mL of peel extract to start the radical antioxidant reaction. The final concentration was 100 µM for DPPH. The reaction mixture was vortexed thoroughly and left in dark at room temperature for 30 min. The absorbance was measured spectrophotometrically at 517 nm and the scavenging activity was calculated using the following equation:

$$\text{DPPH scavenging activity (\%)} = \frac{\text{Abs (control)} - \text{Abs (sample)} \times 100}{\text{Abs (control)}}$$

Preservation experiment

Fresh flayed goat skins were treated with different concentrations of peel powder (2–6% on the green weight of skin) in combinations with salt (10%). Skins with only 10% salt with no peel extract and 40% salt (control) were also preserved. The skins were folded and stored at an ambient

temperature of 32 ± 2 °C. These were monitored daily for physical changes such as smell and hair slip which are indications of putrefaction. The skins were also investigated and assessed for their moisture content, release of HP and bacterial load, to know the efficacy of the bio-based curing process.

The moisture content depicts the amount of water contained in a material; most of the material having water activity of 0.95 supports bacterial growth. Thus, moisture content was used to determine the quantity of water in the skin samples by removing the hair carefully, weighing and further by drying the skin piece in an oven at 105 °C temperature for 4–5 h and the loss of water was calculated according to Bureau of Indian Standards (1971).

For the estimation of HP, skin sample (5 g) was suspended in a citric acid buffer and centrifuged at 12,000 rpm for 15 min. The supernatant was digested with an equal volume of 12 N HCl at 110 °C for 18 h. The digest was evaporated in a water bath and washed with distilled water several times to remove acidity and evaporated. The residue was made up to a known volume and used for HP estimation (Woessner 1961).

For the determination of bacterial load, samples of preserved skin (10 g) were taken and soaked in 100 mL sterile distilled water, and placed on orbital shaker for 30 min at 200 rpm. One millilitre of this solution was serially diluted with sterile normal saline and shaken well. The diluted sample of volume 0.1 mL was poured into a cooling sterile nutrient agar plate and shaken gently clockwise and anticlockwise and allowed to solidify. The plates were incubated at 35 ± 2 °C for 24 h (Cruickshank 1965). The number of colonies on the agar medium was counted.

The thermal stability of the skins is normally assessed by measuring the shrinkage temperature (Nutting and Borasky 1949). Test samples (20 × 3 mm) were taken and hooked in the holder which was then immersed in a bath containing glycerine/water solution in the ratio of 70:30. The temperature was gradually increased by heating. The temperature at which the sample starts shrinking was noted as the shrinkage temperature of that particular skin.

Pollution load generated in soaking process

The spent liquor from control and experimental sample soaking processes were collected and analysed for pollution loads such as biological oxygen demand (BOD), chemical oxygen demand (COD), TDS, total suspended solids (TSS) and chlorides using standard methods. The results are expressed as emission factors (g/kg) of the sample (Eaton et al. 1985).

Physical strength and colour properties of leather

The skins that showed good preservation for 14 days were processed into leather by usual chrome tanning process. These were tested for their physical strength properties. After conditioning the leather at 20 ± 2 °C and 65 ± 2% relative humidity over a period of 48 h, tensile strength, elongation at break and tear strength were measured as per IUP6 (1958) and IUP8 (1960), and assessed in comparison with conventional salt-cured skin.

The samples obtained after chrome tanning and crusts were processed into leather and were subjected to study for difference in colour properties based on reflectance measurements according to the International Commission on Illumination (CIE 191) system of colour measurement with 100 standard observer data (Venugopal and Khambhaty 2020).

Results and discussion

The present investigation was an attempt to study the efficacy of garlic and onion peel (Fig. 1), generally discarded as waste, as a bio-additive for preservation of raw goat skins. The samples were collected and the methanolic extracts were obtained by Soxhlet extraction method and further subjected to analysis of their phytochemical and biological activities. The functional group present in the extracts was identified using FT-IR. Besides, the application of the peel powder on the raw goat skin at different concentrations in combination with salt was carried out and the results were presented. Various tests such as moisture content, HP content and hydrothermal stability were performed and the results were obtained. The skins were further subjected to processing into leathers.

Phytochemical and biological activities

The results of the phytochemical screening showed that the extracts of garlic and onion peel contain flavonoid, alkaloid, glycosides, saponin, steroids, phenols and terpenoids. The phytochemical components present are known to possess both physiological and medicinal activities (Orengo et al. 2016). Alkaloids are very useful in medicine and are used in the production of several valuable drugs (Chaturvedi et al. 2004), whereas flavonoids possess both bacteriostatic and bactericidal effects on some strains of bacteria; furthermore, they are also reported to inhibit the activity of reverse transcriptase and proteases (Havsteen 2002).

The antibacterial and antioxidant property of the peel extracts was examined. The antibacterial assay was performed with the most common bacteria affecting raw skin, i.e. *Bacillus subtilis* and *Staphylococcus aureus.* The results exhibited a zone of inhibition with a 14 and 12 mm diameter

Fig. 1 Peels of white onion and garlic used for preservation experiments

and 16 and 10 mm diameters with garlic peel at 500 µg and 1000 µg, respectively. On the other hand, the onion peel extract exhibited a zone of inhibition with 11 and 13 mm diameter at 500 µg and 1000 µg, respectively, for *B. subtilis*; however, *S. aureus* was not seen to be inhibited.

The antioxidant activity of garlic and onion peel extracts was determined using DPPH method. Several reports have exhibited a close correlation between antioxidant capacity and phenolic content of extracts from various natural sources (Sharma et al. 2014). Since onion peel extract is rich in phenolic compounds, which are known for their ability to act as electron or hydrogen donors, they were expected to have a significant antioxidant capacity whereas the strong antioxidant activity demonstrated by extract from garlic peels was attributed to the presence of certain compounds identified as phenylpropanoids (Ifesan 2014). In the present study, both onion and garlic were observed to have high antioxidant activity > 80% at concentration of 80 and 100 µg/mL, respectively.

FT-IR analysis

The FT-IR analysis was carried out to understand the functional groups present in the garlic and white onion peel extract which are depicted as Fig. 2. The peaks at 2929 and 3293 cm^{-1} are due to the presence of carboxylic acid and basic amino acid groups in the curing extracts. These amino acids are very important to know the type of interaction that curing agents form with raw skin during preservation experiments. These groups have major interactions with skin collagen by weak hydrogen bonding and are reversible in the processing, thus making the extract a safe material for exploitation in skin preservation.

Similar type of amino acids was present in the other type of curing agents that form peaks at 2918 and 3327 cm^{-1}

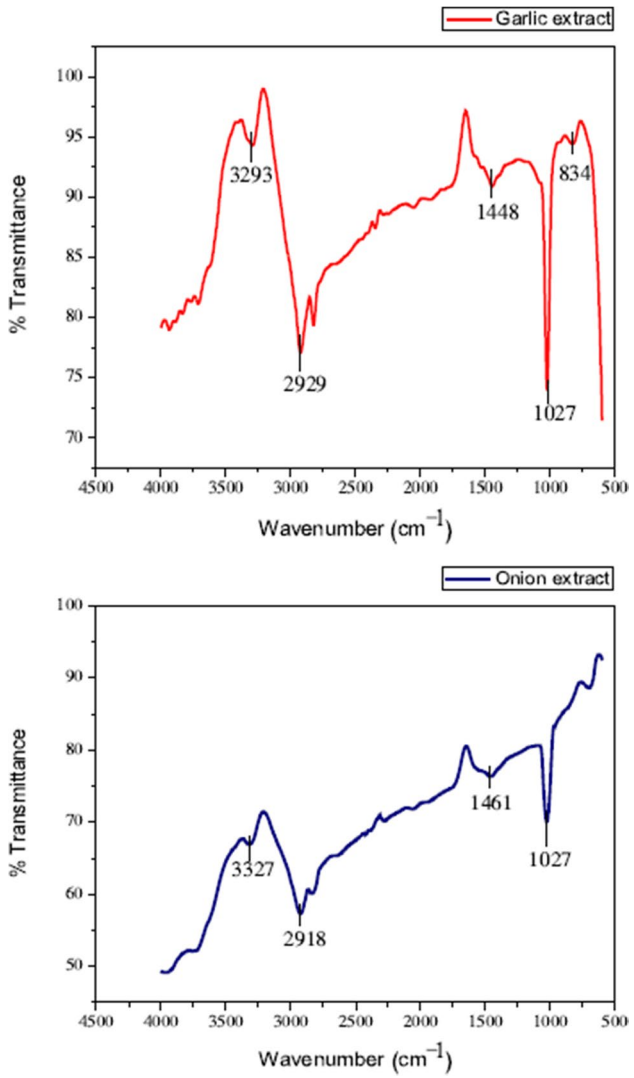

Fig. 2 FT-IR spectra of garlic and onion peels

in onion extract. These groups have also had some similar interactions with skin collagen by forming weak hydrogen bond which are reversible in the processing; and hence, the peel extract is also a safe material that could be successfully used for skin preservation.

Preservation experiments

For preservation experiments, the curing extract prepared from garlic and onion peel was applied on the flesh side of the goat skin at various percentages (based on raw skin weight) and the skin was folded and kept at ambient temperature of 32 °C (Fig. 3). It was observed that the experiment carried out with only 10% salt and 2% of peel powder with 10% salt of both garlic and onion showed hair slip and putrefaction within 2 days. It was thus inferred that the preservation carried out with the help of only 10% salt was unable to preserve the skin due to insufficient bactericidal effect. It is well known that salt at the minimum level of ~ 15–20% is required to preserve the skin at least for a period of 1 week and therefore, the presence of other phytoconstituents in combination with salt might enhance the preservation ability. It is evident from the results that experiments carried out with 4 and 6% of garlic and onion peel powder with 10% salt gave adequate preservation till a period of 14 days with an exception of 4% onion peel with 10% salt, which showed signs of slight putrefaction after ~ 7–8 days of preservation. These experiments revealed no hair slip and putrefaction odour during preservation period. The conventional salt curing with 40% salt (control) also showed excellent preservation as expected. The results were further validated by monitoring other parameters as below.

Determination of moisture content

The moisture content of the experimental and control skin is presented in Fig. 4. As shown in the figure, the moisture content in all experiments was below 60% on day one of preservation. The moisture content of skins preserved with 2% of each peel and only 10% salt was also done which was below 60%; nevertheless, it was not added in the figure since these skins showed signs of putrefaction within two days. Further to that, the experiments carried out with subsequent percentage of garlic and onion peel showed reduced moisture content from the 3rd day onwards which is very much required for the effective preservation system. The

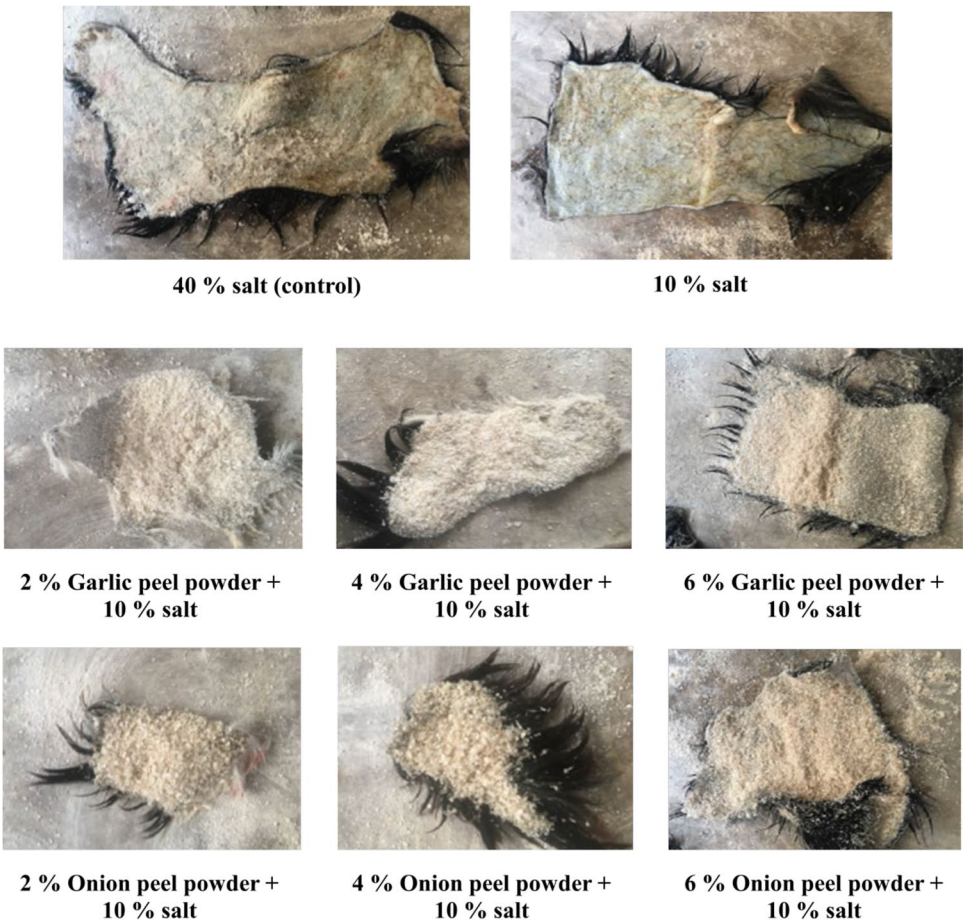

Fig. 3 Preservation experiment carried out with different concentrations of garlic and onion peel powder in combination with salt

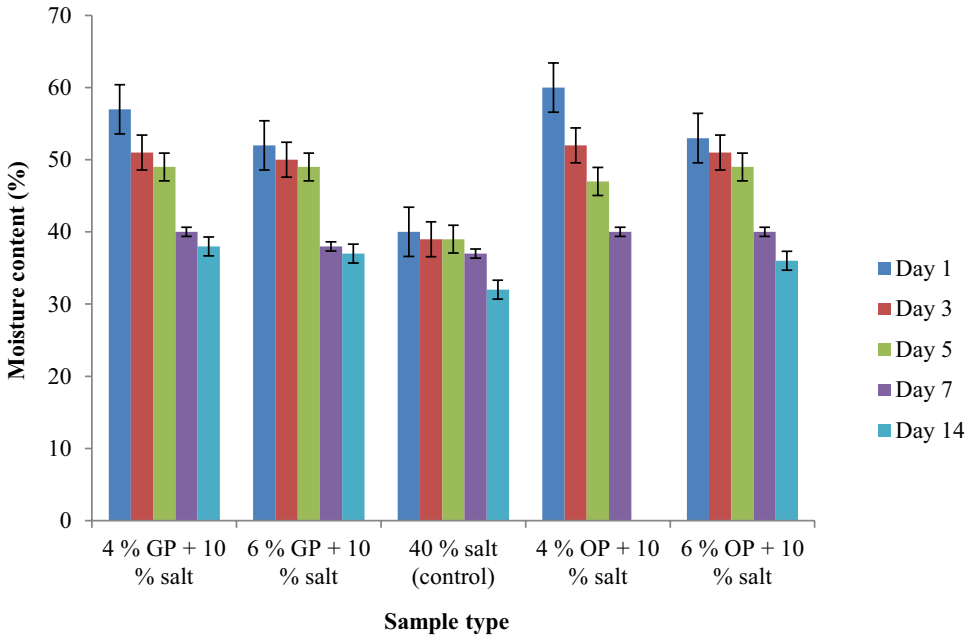

Fig. 4 Moisture content of control and skins preserved with garlic and onion peel at different time intervals

experiments carried out with the less-salt preservation system showed moisture content of 38% and 35% for the garlic and onion peel preserved system respectively in comparison with the moisture content of 32% for the conventional preserved salt system. This clearly illustrates that the garlic and onion peel powder efficiently preserves the skin by means of bacteriostatic and dehydrating property. The conventional salt-cured skins showed steady decrease in the moisture content from 70 to 32% which was due to the fact that salt is a very good de-hydrant and the maximum diffusion of salt is achieved within 24 h of its application (Kanagaraj et al. 2000). Various literature reports that moisture content is one of the critical parameters to be considered in preservation because it controls the activity of bacteria. The moisture content of the raw skin is ~ 65% and during preservation, the moisture content is brought below 40% to a parameter unfavourable for the survival of bacteria (Cooper et al. 1974). Other research carried out using different plants viz., *Cassia fistula*, *Tamarindus indica*, *Psidium guajava*, oiled neem cake, *Citrus limon* based preservation also exhibited similar results (Sivabalan and Jayanthi 2009; Tamil Selvi et al. 2015, 2020; Vinodhkumar et al. 2016).

Determination of HP content

The efficacy of the preservation method can also be validated by quantitative release of HP in the soak liquor. Hydroxyproline is an amino acid that is present only in the skin/hide. If any sort of degradation occurs to the skin/hide due to improper curing, the presence of HP will be higher in the soak liquor. The HP is expressed per gram of muscle tissue wet weight as a quantitative measure of amino acid from collagen fibres; the results are presented in Table 1. The release of HP in the experiments 1 and 2 carried out with only 10% salt and garlic and onion peel (2%) in combination of 10% salt showed a rise in the HP within 2 days of preservation. Also, in the case of sample preserved with 4% onion peel in combination with 10%

Table 1 Effectiveness of garlic and onion peel preservation by estimating the hydroxyproline content in soak liquor

Experiment no		µg of hydroxyproline/g of skin				
		Day 1	Day 3	Day 5	Day 7	Day 14
0% peel powder + 10% salt (1)		3.4	11.5	-	-	
2% peel powder + 10% salt (2)	Garlic	4.1	12.9	-	-	-
	Onion	4.3	14.2	-	-	-
4% peel powder + 10% salt (3)	Garlic	2.9	3.0	3.1	3.2	4.5
	Onion	2.5	3.4	5.7	10.7	-
6% peel powder + 10% salt (4)	Garlic	2.6	3.5	3.1	3.7	4.1
	Onion	2.5	3.6	3.4	3.9	4.4
40% salt (5)		2.9	3.5	3.6	3.7	3.6

salt exhibited a rise in HP by day 7 combined with signs of putrefaction. Nevertheless, experiments 4 and 5 gave very good preservation ability even till day 15, which was validated by detection of very low amount of HP in the soak liquor. The results indicate good preservation ability by both the peels; however, garlic peel took an upper position. The curing agent forms weak binding with collagen; therefore, it is reversible system. If the curing/preservation system is not efficient, it may lead to structural destabilization of the skin finally resulting to putrefaction which is not desirable. These results satisfy the antibacterial property of the peel powder against skin-putrefying bacteria and are in line with other studies that have reported very low levels of HP at the end of curing period which ranged from about 4 μg g^{-1} of skin to 4 mg g^{-1} of skin which was either reduced or stabilized as compared to previous data (Tamil Selvi et al. 2015, 2020; Vinodhkumar et al. 2016).

Bacterial load

The curing system can be also evaluated by means of bacterial load in the preserved skin. Presence of huge bacteria in the skin is a direct indication for the performance of the curing system. The total viable count of bacteria is studied by serial dilution techniques and presented in Table 2. It is evident from the table that the bacterial population shows higher number in the initial period from day 1 to 5 which eventually decreased as the duration increased. This was very much in line with the results of HP content. The results of 6% garlic and onion peel were quite comparable to that of conventional 40% salt preservation by the end of 14 days. A decrease in the bacterial count at the end of curing period is a well-known indication of the efficacy of the curing process. Similar observation has been made with other studies.

Table 2 Determination of bacterial load in the skins preserved with garlic and onion peel in combination with 10% salt and control

Experiment	No. of colonies (10^{-3}/g of skin)				
	Day 1	Day 3	Day 5	Day 7	Day 14
Salt (10%)	180	240	-	-	-
Garlic (2%)	200	280	-	-	-
Onion (2%)	250	300	-	-	-
Garlic (4%)	150	97	60	30	12
Onion (4%)	190	156	96	180	-
Garlic (6%)	165	95	50	23	`8
Onion (6%)	178	87	55	27	9
Salt (40%) (control)	20	10	8	6	2

Hydrothermal stability

The hydrothermal stability measured in terms of shrinkage temperature is one of the direct indicators of structural stability. Shrinkage temperature is an index of any structural changes in the skin matrix (Babu et al. 2012). The destabilization of the collagen molecules could be easily found out by carrying out shrinkage temperature measurements for the preserved skin. The shrinkage temperature of the preserved skins at different time intervals of the current study is depicted in Table 3. There is no significant change in the shrinkage temperature of the salt-cured and peel extract (6%) cured skins showing that there is no deleterious effect on the skin matrix by the newly developed preservation method. It is also evident from the table that the curing agents do not increase the shrinkage temperature drastically and the types of bonds formed are of weak type and are reversible. Similar results have been obtained when leaves paste of *Clerodendrum viscosum* (Hashem et al. 2017) and dried neem leaves (Velappan et al. 2021) were used concluding that the use of leaves paste does not modify the stability of the collagen matrix in goat skin.

Determination of pollution parameters

The skins that remained in a good condition for 14 days were taken further for leather processing and tanned into leather. The first operation of leather processing is called soaking where skins are washed with water to remove curing agents and to rehydrate the skin. The soak liquor shows the presence of pollution load especially BOD, COD, TDS and chlorides. The pollution loads were analysed and presented in Table 4. The experiments carried out with the help of garlic peel and onion peel at 4% plus 10% salt and 6% peel with 10% salt were analysed for emission factors. It is seen from the table that the BOD and COD values were reduced to the level of ~ 25% and 13%, respectively, over the control sample, whereas the chlorides drastically reduced by ~ 76%. The TDS and TSS values were reduced to the level of ~ 75% and 70%, respectively, over conventional salt curing systems. It is evident that the garlic and onion peel not only produced

Table 3 Shrinkage temperature (°C) of preserved skins

No. of days	Garlic peel (6%) preserved skin	Onion peel (6%) preserved skin	Salt 40%
1	70 ± 2	71 ± 2	70 ± 2
3	69 ± 2	68 ± 2	69 ± 2
5	70 ± 2	69 ± 2	70 ± 2
7	70 ± 2	70 ± 2	71 ± 2
14	71 ± 2	71 ± 2	71 ± 2

Table 4 Determination of pollution parameters in the soak liquor of bio-based and conventional curing systems

Parameters	Emission factors in soaking process (g/kg)				Permissible limits* (mg/L)
	Garlic peel 4% + salt 10%	Garlic peel 6% + salt 10%	Onion peel 6% + salt10%	Salt – 40%	
BOD	6.9 ± 0.5	7.2 ± 1	6.8 ± 0.5	8.9 ± 0.4	30
COD	21.3 ± 0.8	26.3 ± 0.8	26.1 ± 0.4	30.2 ± 0.5	250
Chlorides	45.1 + 0.5	46.23 ± 0.2	46.48 ± 0.7	185.2 + 0.6	600
TDS	65.4 ± 1.2	72.4 ± 1.2	73 ± 1.5	272.6 ± 4.8	2100
TSS	20.5 ± 1.0	22 ± 2	26 ± 1	81.0 ± 4.2	100

*Adapted from Saxena and Bharagava (2015)

Table 5 Physical testing of crust leathers preserved using bio-based and conventional curing systems

Sl. No	Garlic peel 4% + salt 10%	Garlic peel 6% + salt 10%	Onion peel 6% + salt 10%	Salt – 40%
Tear strength, *N*	24.90 ± 0.5	34.15 ± 0.6	37.26 ± 0.3	36.67 ± 0.5
Elongation at break, %	56.01 ± 1.2	55.68 ± 1	51.18 ± 1.2	50.51 ± 1.0
Tensile strength (N/mm^2)	9.33 ± 0.5	9.68 ± 0.5	8.64 ± 0.5	9.67 ± 0.5
Shrinkage temperature (°C)	105	104	103	103

effective preservation but also reduced pollution load to the highest level.

Physical strength testing and colour properties

The preserved skins were further soaked, limed, de-limed, pickled and tanned to wet blue leather and further processed to crust leather and physical strength such as tensile strength, elongation at break, tear strength, load at grain crack and distension at grain crack were measured (Table 5). Leathers produced from the experimental skins showed comparable strength properties to the conventional salt-cured sample.

The crust leather produced after the tanning process was subjected to colour measurement using CIELAB system (Table 6). The CIELAB system is adopted for the measurement of colour difference. *L*, *a* and *b* are colour co-ordinates and *h* is the hue. *a* and *b* are red-green and yellow-blue colour differences and chromaticity differences, respectively. The experimental leather produced showed comparable colour properties as that of salt-cured leather. It is inferred from the *L* value that when lightness increases, the shade become lighter in the case of experimental samples. The increase in *a* and *b* values indicates that the shade has become more green and less yellow when compared with the control samples. It can also be observed that the chromaticity and hue differences are higher in the experimental sample compared to the control samples. The overall colour differences for the experimental samples carried out showed – 1.305, – 1.496 and – 1.791 values compared to – 4.924 value of salt-cured leather sample. The leather produced with the experimental skins showed comparable colour and strength properties when compared to the control samples. Hence, garlic peel and onion peel have the potential to emerge as viable alternative to conventional salt-based preservation.

Table 6 Colour measurements of crust leathers preserved using bio-based and conventional curing systems

Colour measurement of crust leather from cured goat skins				
Sample no	L	a	b	DL
Garlic peel 4% + salt 10%	70.148	– 2.025	60.411	– 1.305
Garlic peel 6% + salt 10%	72.177	– 2.016	62.671	– 1.406
Onion peel 6% + salt 10%	72.410	– 2.186	61.417	– 1.691
Salt 40%	68.720	– 1.748	59.078	– 4.914

Conclusion

In the current investigation, garlic peel and onion peel have been investigated for their possible usage for preservation of raw goat skins. The main reason for selecting these substrates was their excellent antibacterial and antioxidant properties. The extract of garlic peel and onion peel

along with reduced salt was found to successfully preserve freshly flayed goat skins for 14 days. The moisture content was found to reduce from 38 to 35%, eventually reducing the bacterial load, further validated by very low release of HP for all experimental samples. The pollution load was reduced appreciably especially TDS at the level of 63–83% in the experimental samples. The experimental skins and control (40% salt based on green weight) were processed into leathers and subjected to physical strength and colour properties. The results showed comparable findings with that of conventional technique. This work was carried out with a dual purpose: (i) utilization of peels of garlic and onion, which are available in plenty and discarded as waste, (ii) exploiting the excellent antimicrobial property of these peels for preservation of raw goat skin. This study paves a new way of curing the raw skins and hides, thus averting the pollution caused by salt in tanneries leading to the development of a cleaner curing technique.

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Author contribution AT, conceptualize of the work, reviewing final draft; YK, supervision, review and editing of draft manuscript; SS, investigation, experimentation and analysis; GCJ, suggestions, review and editing.

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Data availability Not applicable.

Declarations

Ethics approval This article does not contain any studies with human participants or animals performed by any of the authors.

Consent to participate Not applicable. This manuscript does not contain any studies with human participants or animals performed by any of the authors.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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