Combining an Analytic Hierarchy Process and TOPSIS for Selecting Postharvest Technology Method for Selayar Citrus in Indonesia

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Abstract. This research was intended to select the best handling methods or postharvest technologies that can be used to maintain the quality of citrus fruit in Selayar, South Sulawesi, Indonesia among (1) modified atmosphere packaging (MAP) (2) Controlled atmosphere storage (CAS) (3) coatings (4) hot water treatment (5) Hot Calcium Dip (HCD) by using combination between an analytic hierarchy process (AHP) and TOPSIS. Improving quality, applicability, increasing shelf life and reducing cost are used as the criteria to determine the best postharvest technologies. The results show that the most important criteria for selecting postharvest technology is improving quality followed by increasing shelf life, reducing cost and applicability. Furthermore, by using TOPSIS, it is clear that the postharvest technology that had the lowest ranking is modified atmosphere packaging (MAP), followed by controlled atmosphere storage (CAS), coatings, hot calcium dip (HCD) and hot water treatment (HWT). Therefore, it can be concluded that the best postharvest technology method for Selayar citrus is modified atmosphere packaging (MAP).

1. Introduction
Selayar regency is one of the main citrus fruit producing regions in South Sulawesi, Indonesia. The harvest of citrus fruit in a large scale has brought the consequences in the postharvest deterioration[1,2]. Postharvest deterioration of citrus fruit could be caused by many factors, including metabolic changes, (biochemical changes associated with respiratory metabolism, ethylene biosynthesis and action, and compositional changes), growth and development (anatomical and morphological changes), physical injuries, water loss, physiological disorders, and pathological breakdown. On the other hand, citrus postharvest quality and shelf life are becoming increasingly aspects, as consumers expect the quality fruit to be available throughout the year [1]. Therefore, harvesting and handling hold the key to getting desired results from postharvest treatments.

Some handling methods or postharvest technologies can be used to maintain the quality of citrus fruit, such as: modified atmosphere packaging (MAP)[3–6] and controlled atmosphere storage (CAS) [7], coating or waxing[8–11], hot water treatment[12,13] and hot calcium dip [14]. However, every method has drawbacks and advantages in preserving citrus fruit. Therefore, the main objective of this research is to select the best postharvest technology by combining analytic hierarchy process (AHP) and TOPSIS.
Some studies on constructing and applying AHP or TOPSIS have been conducted. Alphonce (1997), have applied AHP models in agriculture in developing countries. In his study, decision hierarchies have been suggested for: (a) determination of farm portions to allocate to each of the food crops; (b) resource allocation to agricultural activities; (c) best location for a village store; (d) choice between subsistence and cash crops production and (e) determination of the crop production technology[15]. Chavez et al. [16] investigated criteria and farming activities for tobacco diversification by AHP. The results showed that livestock activities and spring–summer crops are important alternatives for tobacco production. Chen et al [17] used AHP to determine the optimum edible film for preserving kiwifruits. Amiri (2010) combined AHP and TOPSIS to select project for oil-fields development[18]. Another study by Berdie (2017) also combined AHP and TOPSIS in the field of integrated software systems[19]. From the above studies, it can be concluded that AHP and TOPSIS can be applied to the agriculture sector. However, little attention has been given so far to the application of the AHP to the postharvest technology, although the AHP seems to be suitable also to sector of postharvest technology [20].

Our previous study suggests that AHP is suitable for selecting postharvest technology method for citrus fruit in Japan[1]. However, in this study we only proposed AHP to determine the best postharvest technology for citrus in Japan. The present study was, therefore, conducted to select the best postharvest technology for Selayar Citrus by combining analytic hierarchy process (AHP) and TOPSIS. The AHP is used to score and set the share of importance of the relative weights for the decision criteria – sets and the TOPSIS method is used to obtain the final ranking.

2. Method

2.1. The analytic hierarchy process

This study was quantitative research which employed the application of AHP for selecting postharvest technology method for citrus fruit in Selayar regency, Indonesia. The AHP method is one of the multi-criteria decision analyses, and is applicable to solving problems containing more than one decision criterion. This method is a mathematically based, was introduced by Saaty (2008)[21]. It uses the pairwise comparison method to rank order alternatives of a problem that are formulated and solved in a hierarchical structure. Briefly, the step-by-step procedure in using AHP is the following [22]:

1. Define decision criteria in the form of a hierarchy of objectives. The hierarchy is structured in different levels: from the top (i.e. the goal) through intermediate levels (criteria and sub-criteria on which subsequent levels depend) to the lowest level (i.e. the alternatives). In this study, we are dealing with a multiple decision problem, the aim of which is to select postharvest technology for fruit citrus. The highest level of the hierarchy is the goal of the problem, the second level is the criteria as applied to the ranking of postharvest technology (improving quality, increasing shelf life, reducing cost and applicability), while the third one is the decision variants, i.e. modified atmosphere packaging (MAP), controlled atmosphere storage (CAS), coatings, hot water treatment (HWT), and hot calcium dip (HCD).

2. Weight the criteria, sub-criteria and alternatives as a function of their importance for the corresponding element of the higher level. For this purpose, AHP uses simple pairwise comparisons to determine weights and ratings so that the analyst can concentrate on just two factors at one time. One of the questions which could be asked in using a pairwise comparison is: how important is the “improving quality” factor with respect to the “increasing shelf life”, in terms of the goal for “selecting postharvest technology method for Citrus fruit”? The answer may be “equally important”, “moderately more important”, etc. The verbal responses are then quantified and translated into a score via the use of discrete 9-point scales that we can see in Table 1. In principle, the evaluators are expected to express their ratings in odd numbers (1, 3, 5, 7 and 9), while even numbers (2, 4, 6 and 8) are used where there is no consensus in the group of evaluators.
Table 1. Judgement scores in AHP.

| Judgement                        | Explanation                                                                 | Score |
|---------------------------------|-----------------------------------------------------------------------------|-------|
| Equally                         | Two attribute contribute equally to the upper-level criteria                 | 1     |
| Between equally and moderately  | Experience and judgement slightly favour one attribute over another         | 2     |
| Moderately                      | Experience and judgement strongly favour one attribute over another         | 3     |
| Between moderately and strongly | An attribute is strongly favoured and its dominance demonstrated in practice | 5     |
| Strongly                        | Experience and judgement strongly favour one attribute over another         | 4     |
| Between strongly and very strongly| An attribute is strongly favoured and its dominance demonstrated in practice | 6     |
| Very strongly                   | An attribute is strongly favoured and its dominance demonstrated in practice | 7     |
| Extremely                       | The evidence favouring one attribute over another is of the highest possible order of affirmation | 8     |

3. After a judgment matrix has been developed, a priority vector to weight the elements of the matrix is calculated. Priority vectors (w) are obtained from the pairwise comparison matrix (A) by solving an eigenvalue problem in the following relation (Eq. 1):

\[ Aw = \lambda_{\text{max}}w \]

where \( \lambda_{\text{max}} \) is the highest matrix eigenvalue.

4. Evaluate the soundness of the judgements with the inconsistency ratio \( I_R \). This is a peculiarity of the AHP technique. Before determining an inconsistency measurement, it is necessary to introduce the consistency index (CI) of an \( n \times n \) matrix (of judgements) defined by the ratio (Eq. 2):

\[ CI = \frac{\lambda_{\text{max}} - n}{n-1} \]  

Then, \( I_R \) is defined as the ratio (Eq. 3):

\[ I_R = \frac{CI}{RI} \]

where RI is the corresponding average random value of CI for an \( n \times n \) matrix. Judgements can be considered acceptable if \( I_R \leq 0.1 \). In cases of inconsistency, the assessment process is immediately repeated for the inconsistent matrix. An inconsistency ratio of 0.1 or more may warrant further investigation. Analyses using the AHP method can be performed easily and quickly with the support of numerous available IT tools. In this study, all AHP analyses were performed using the Expert Choice ver 11.

2.2. Topsis

The final stage in order to achieve the proposed objectives is to apply the TOPSIS method. The basic principle of this method is that the optimal decision shall be as close as the most advantageous solution and as far away as the worst solution. This method is often criticized for its inability to adequately handle the inherent uncertainty and imprecision associated with the mapping of the decision-maker’s perception to crisp values. In the traditional formulation of the TOPSIS, personal judgments are represented with crisp values. However, in many practical cases the human preference model is uncertain and decision makers might be reluctant or unable to assign crisp values to the comparison judgments[18]. The ideal solution should have a rank of one and the worst alternative should have a rank approaching 0 [19,21,23].

Through the proposed model, the TOPSIS method involves the following steps:

- Construction of the decision matrix. This step leads to the Table 1 whose configuration is the decisional matrix.
- Calculation of the normalized decision matrix. The goal of normalization is to transform different dimensional attributes into dimensionless attributes.
3. Results and discussion

There are two types of pairwise comparisons in this study. The first type describes pairwise comparisons of elements of the criteria with respect to the goal as shown in Table 2. One of the question being asked is this: “Comparing reducing cost and applicability, which one more dominates for the selecting postharvest technology method for Citrus fruit and by how much important?” The resulting priority vector, the maximum eigenvalue (λ\text{max}) and the inconsistency ratio (IR) are shown in Table 2.

| Goal | Local priority vector |
|------|-----------------------|
| Improving quality | 0.636 |
| Increasing shelf life | 0.117 |
| Reducing cost | 0.117 |
| Applicability | 0.130 |

\[ \lambda_{\text{max}} = 4.112, \text{IR} = 0.0039 \]

The second type describes pairwise comparisons of the elements of postharvest technology alternatives with respect to their parent criteria element as shown in Figure 1, 2, 3 and 4. For the example, the question being asked in Figure 1 is : “Comparing coatings/pelilinan and hot water treatment, which one more dominates the improving quality criteria, and by how much important?”

The Figure 1, 2, 3, and 4 display the local priority vectors of each pairwise comparisons matrix with their corresponding maximum eigenvalues and inconsistency ratio (IR). IR values range from 0.0039 to 0.05 which satisfy the 0.10 threshold.

After applying the TOPSIS algorithm the preferred postharvest technology in terms of performance is the modified atmosphere packaging (MAP) (0.354), because she results with minimum score. This hierarchy is considered valid for the defined selection criteria and their corresponding weights.
4. Conclusion
The postharvest technology is method to maintain the quality of citrus fruit and to choose the best candidate by using a multi-criteria approach that using linguistic preferences can be very useful for uncertain situations. The AHP is used to analyze the structure of the best postharvest technology and to determine weights of the criteria, and fuzzy TOPSIS method is used to obtain final ranking. Proposed model results indicate that modified atmosphere packaging (MAP) is the best alternative with CC value of 0.354. In the application, it is shown that calculation of the criteria weights is important in fuzzy TOPSIS method and they could change the ranking for other project.

5. References
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