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Standardization of hot air drying parameters and their impact on total phenolics and oil content of mango seed kernel

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Abstract

The mango seed kernel (MSK) stands out as a rich source of total phenolic compounds and premium-quality fats. This study aimed to optimize the hot air drying process parameters for MSK, utilizing a tray dryer to achieve maximum yield of mango seed kernel oil (MSKO) while retaining high levels of total phenolic compounds. The experimentation involved the application of a Completely Randomized Design (CRD) analysis, leading to the identification of the optimal drying conditions- 60°C temperature, resulting in a yield of 11.80% MSKO and 163.28 mg gallic acid equivalents (GAE) per gram of MSK, with a desirability index of 0.861.After establishing the standard hot air drying parameters, the biochemical composition of MSK showed enhancement due to the effective preservation of bioactive compounds, particularly total phenolic compounds. This extensive experiment not only improves the yield of MSKO but also enhances the nutritional value of MSK. The findings highlight the potential for additional investigation and utilisation of mango seed kernel in food and bioenergy applications.

Key words: Mango seed kernel (MSK), mango seed kernel oil (MSKO) yield, total phenolic content, tray dryer.

Introduction

Mango (*Mangifera indica* L.), celebrated as the "King of Fruit," is renowned for its distinctive flavour and remarkable nutritional content. Comprising pulp, peel, and kernel, the mango fruit is a reservoir of reducing sugars, amino acids, aromatic compounds, and functional constituents such as pectin, vitamins, anthocyanins, and polyphenols, predominantly found in the pulp (Rajan, 2021).

While the pulp takes precedence as the primary edible portion, the peels and kernels, often dismissed as bio-waste, harbor substantial nutritional value. Noteworthy functional components, including protocatechuic acids, mangiferin, and carotenes with antibacterial, antidiabetic, anti-inflammatory, and anticarcinogenic properties, elevate the peels beyond mere byproducts of mango processing (Rajan, 2021).

The mango seed kernel (MSK) emerges as a potent source of polyphenols and antioxidants, surpassing the pulp and peel in these bioactive constituents. Separated from the mango stone through decortication, the MSK's phenolic antioxidant, metal chelator, and tyrosine inhibitor content make it a valuable resource. Factors influencing MSKO content, such as variety, soil, climate, ripening stage, harvesting time, and extraction methods, necessitate tailored approaches in its utilization (Yamoneka *et al.*, 2015; Sani, 2014).

Research has illuminated the MSK's potential as a rich source of phytosterols, including campesterol, beta-sitosterol, stigmasterol, and tocopherols, adding to its nutritional significance. Moreover, the presence of mangiferin, ferulic acid, tannins, gallic acid, ellagic acid, vanillin, cinnamic acid, and unidentified substances further accentuates the diverse composition of this often-overlooked bio-resource (Maisuthisakul and Gordon, 2009; Abdalla *et al.*, 2007a; Ashoush and Gadallah, 2011).

In the evolving landscape of oils and fats, unconventional sources, such as fruit seeds, nuts, and lesser-known plants, have become focal points for lipid exploration. Within this context, MSK offers unique lipid possibilities, aligning with innovations in the oils and fats industry (Choudhary 2023).

Critical to the efficient extraction of functional components and the preservation of bioactive compounds against enzymatic degradation is the pivotal technological process of drying MSK. This procedure stabilizes the product, enhances extraction yields, and safeguards textural and nutritional values. However, suboptimal drying conditions can lead to physicochemical reactions, compromising product quality (Banerjee *et al.*, 2016). Recognizing the influence of temperature and drying time on the activity and stability of bioactive compounds, optimizing drying parameters is paramount to ensuring the desired quality of MSK-derived products. This study addresses this essential step, contributing insights into the optimization of MSK drying processes for enhanced product quality.

Materials and methods

Mango seed kernel: The method involved manually separating industry byproducts, excluding mango peels. The mango seed stone was sun-dried to reduce moisture for the study. After drying, the stones were hammered to separate components. By carefully splitting the broken-down stones, mango seed kernels (MSK) and shells were separated. A thorough removal process removed the MSK's thin papery layer. Using the refined MSK, free of unwanted components, as the primary material for the subsequent research study ensured the integrity and relevance of the experimental procedures and findings.

Biochemical analysis of MSK and MSK powder: Biochemical analysis of raw MSK and standardized MSK powder was analysed

as per guidelines specified in AOAC (2019). The moisture content in the samples was determined through the gravimetry determination method using hot air oven. To estimate of the crude fat content, SOCS plus instrument was utilized. Crude fiber estimation was carried out using the Fibra-plus instrument by acid- alkali wash method. The protein content was evaluated using the Kjeldahl method and the final protein content was calculated using the formula: % Nitrogen × 6.25. Ash content was determined using a muffle furnace.

Experimental design: Completely randomized design was used in experimentation with five replications. The independent and dependent variables for standardization process parameter of hot air drying of MSK were temperature (°C) 50, 60, 70 and total phenolic content (mg GAE/g)**,** MSKO content (%), respectively.

Estimation of moisture content: Moisture content of raw mango kernel and dried mango kernel powder was determined by gravimetric method. In this method a change in mass of the sample was measured as a function in temperature while the sample is subjected to controlled temperature. About, 5 g sample was weighed in an empty aluminum moisture dish. Removal of moisture was carried out in hot air oven at 105±2°C. After each hour weight of aluminum moisture dish was measured until constant weight was obtained. Calculation was done using following equation.

$$\text{Moisture Content (\%)} = \frac{\text{Initial weight-Final weight}}{\text{Weight of sample}} \times 100 \quad (2)$$

MSKO content: MSKO content of sample was determined by semi-automatic type of Socs Plus (Make: Pelican Equipments, Chennai). Empty flasks were properly cleaned and labeled and weighed. 2 g of samples were weighed and put into a thimble. The thimble was kept into flasks that have been already weighed. The flasks were then fixed in Socs Plus. Approximately 80 mL of petroleum ether was poured into the Soxhlet flask at the top of the extraction tube using funnel. The condenser was attached to the topside of extraction tube. The estimation of content process was divided into two cycles: The first was of one hour for refluxing, during which fat was extracted from the samples, and the second was of 30 min for solvent recovery, during which temperature of heating was high and solvent was collected in the tubes by shutting the valve off. The thimbles were then removed from the flasks once the process was completed. After this flask was kept in oven to dry the traces of solvent then flasks were kept in desiccator to prevent the absorption of moisture till cool. After these flasks were weighed. The MSKO content in the sample was calculated as per the following equation.

$$\text{MSKO content (\%)} = \frac{\text{Initial weight -Final weight}}{\text{Weight of MSK powder}} \times 100 \quad (2)$$

Estimation of total phenolic content: Total phenolic content was determined by the method given by (Bloor, 2001) with slight modifications. Exactly half gram of sample was weighed and extracted with 20 mL of methanol diluted with water in the ratio 3:2 v/v. The mixture was centrifuged at 700 *g* for 10 min at room temperature. The supernatant obtained was adjusted to 25 mL in a volumetric flask. Aliquot of supernatant was used for analysis of total phenolic content of MSK. 0.5 mL of the extract were mixed with 2 mL of Folin-Ciocalteu's reagent (diluted 1:10 with distilled water). Then 4 mL of 7.5% w/v sodium carbonate solution was added. The solution was kept undisturbed in dark for 30 min at room temperature. Then the absorbance of the mixture was measured at 765 nm using UV-VIS spectrophotometer. The Gallic acid equivalent value was calculated using gallic acid standard curve as per the following linear equation and presented as mg of GAE/g of the extract.

$$Y = 0.00756X - 0.00015 \qquad R^2 = 0.998 \quad (3)$$

Results and discussion

Biochemical composition of MSK: Determining the nutritional value of a by product is crucial and one key aspect for this assessment is proximate composition. Measurements for each parameter were taken three times, and the average values were depicted in the Table 1. The results obtained for biochemical composition of MSK were in agreement with the data obtained by (Nzikou *et al.,* 2010; Siaka, 2014; Kaur and Brar, 2017; Abdelaziz, 2018; Das, 2022; Chaudhary *et al.,* 2023). Present study showed that MSK moisture content was in the range of reports by (Dhingra and Kapoor 1985; Abdalla *et al.,* 2007a; Muchiri *et al.,* 2012). Raw MSK contains higher amount of protein content than reported by Dhingra and Kapoor (1985). Higher content of protein in raw MSK was observed might be due to the difference in variety. Considering that MSK from mango variety kesar has considerable very high protein content. While, Seleim *et al.* (1999) revealed that protein quality of MSK is good. MSK fat is a promising and safe source of edible oil that is nutritious and without any anti-nutrients and therefore is emerged as substitute for any solid fat (Rukmini and Vijayaraghavan, 1984). Mwaurah *et al.* (2020) reported fat values in MSK in the range of 6-15.2% fat which is similar to our results. Gumte *et al.* (2018) stated that MSK contains crude fiber 2.23%. Choudhary *et al.* (2023) reported carbohydrate values for MSK 53.34 to 76.81%. The high protein and fat content are substituted for carbohydrate.

Table 1. Biochemical composition of mango seed kernel (MSK)

Parameter	Composition of MSK	Composition of MSK powder
Moisture (%)	37.17±0.15	4.32±0.10
Protein (%)	7.89±0.59	9.7±0.05
Fat (%)	9.68±0.21	11.86±0.24
Crude fiber (%)	1.17±0.42	2.25±0.25
Ash (%)	1.33±0.12	2.59±0.35
Carbohydrate (%, by difference)	43.93±0.52	71.53±0.55
Total phenolic content (mg GAE/g)	± 20.71	185±29.32

*Values are represented as mean±SD (n=3)

Total phenolic content in MSK was found to be 265±20.71 mg GAE/g. The total phenolic contents in MSK varied widely across different mango varieties, with values ranging from 1.12 to 447.60 mg GAE/g seed (Abdalla *et al.,* 2007b; Ribeiro *et al.,* 2008; Sogi *et al.,* 2013; Dorta *et al.,* 2014). MSK from mango var. Kesar found to be rich in total phenolic content, this may be due to the differences in geographical location, mango cultivars, and extraction conditions. Differences in biochemical composition of MSK can be attributed due to variances in plant varieties, cultivation conditions, fruit ripeness, seed kernel harvest timing, and the chosen extraction methods.

Effect of different drying temperatures on the moisture content of MSK: The standardization process for hot air drying of MSK was centered around the goal of obtaining the maximum MSKO yield along with optimum retention of total phenolic content. Tray drying of MSK was conducted at 50, 60 and 70°C temperatures. Drying was carried out till 4-5% moisture content achieved on dry basis. Thickness of MSK was kept constant during the drying process. During the drying process, data of moisture loss were collected at regular intervals of 1 h. These data served as the basis for calculating the drying time required for each condition. Additionally, the collected data were utilized to generate a graph illustrating the relationship between moisture content on dry basis and the corresponding drying time (Fig 1). Also, the collected data were utilized to generate exponential graph illustrating the relationship between moisture ratio and the corresponding drying time along with R^2 and equation (Fig 2).

The tray drying process at a temperature of 50°C required the maximum drying time of 480 min to achieve the desired moisture content. In contrast, the shortest drying time of 360 min was observed at a temperature of 70°C. Drying of MSK at 60°C required 420 min to achieve desired moisture content. Drying at 50°C temperature requires more time to reduce moisture content of MSK, when all parameters like thickness of MSK, initial weight of MSK loaded in tray, placement of tray inside tray dryer etc. were kept constant. These results demonstrated the influence of temperature on the hot air-drying process of MSK. Results showed that higher temperatures leading to shorter drying time and vice versa. An increase in temperature led to a considerable variation in the duration required for the hot air drying of MSK, which could have a substantial impact on the quality attributes of MSK.

During the initial drying period, the moisture content decreased significantly over time. However, in the final period, the drying rate slowed down due to a reduced driving force. Similar observations were reported for the drying of various agricultural by-products, such as MSK (Ekorong *et al.*, 2015), olive cake (Vega-Gálvez *et al.,* 2010) and prickly pear seed (Motri and Zagroub, 2013) using different temperatures. Increased drying temperatures led to a swift reduction in the moisture content of MSK, promoting the outward migration of moisture from the samples. (Mphahlele *et al.,* 2019).

The observation suggests that a reduction in moisture content

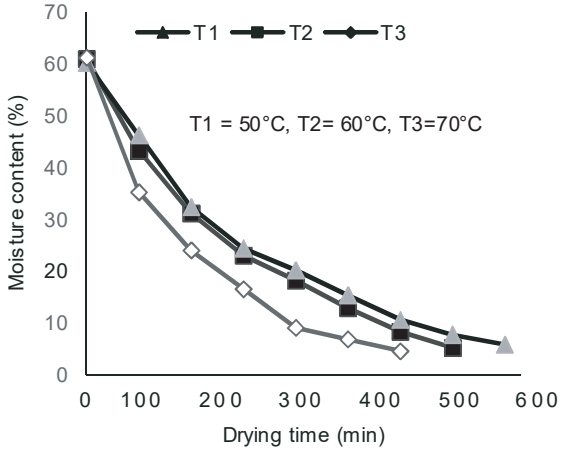

Fig. 1. Moisture content dry basis percentage versus drying time curves for tray drying of MSK

led to an increase in vapor permeability, and the pores' structure remained open. Because the seed kernel has a substantial loss factor at higher moisture levels, it absorbs heat quickly during the initial drying phases, causing a rapid temperature rise. As a result, the pressure of water vapor within the seed kernel's pores increases, causing them to open up. This indicates that moisture transport during the initial drying phase is primarily driven by the diffusion of liquid moisture. As drying progressed, vapour diffusion became the major method of moisture diffusion in the final stages of drying (Pickles, 2003; Sharma *et al.,* 2005; Reyes *et al.,* 2007; Celma *et al.,* 2012).

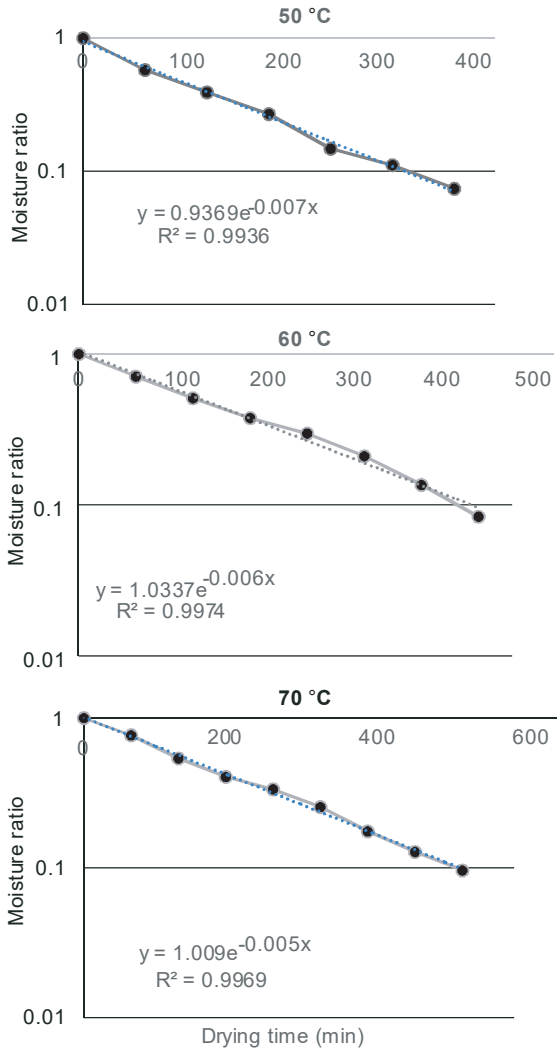

Fig. 2. Moisture ratio versus drying time curves for tray drying of MSK

Effect of different drying temperatures on the MSKO yield: The drying process for MSK was conducted at three distinct temperatures *i.e.*, 50, 60 and 70 °C. increased from 50 to 60°C MSKO yield was increased but when it increased from 60 to 70°C the yield of MSKO was slightly decreased. MSKO yield upon drying at temperature 50, 60 and 70 °C obtained were 10.27±0.04%, 11.83±0.03, 11.23±0.06 %, respectively. These results were consistent with the findings of Ekorong *et al.* (2015). At 40°C, the MSKO yield was 8.64 %. This yield increased to 9.10 % at 60 °C but decreased to 8.15 % when the temperature was further increased to 80°C.

Autooxidation and loss of volatile components might led to decline in MSKO yield when exposed to a temperature of

70°C. As the drying temperature and oxygen levels increased, the oxidation of MSKO and loss of volatile compounds were accelerated. Elevated temperatures increase the susceptibility of polyunsaturated fatty acids to oxidation. This could have been essentially unavoidable since polyunsaturated triglycerides in MSKO might have played a part in that oxidation (Tallman *et al.,* 2004). Moisture content, metal presence, enzyme activity, ultraviolet (UV) radiation, protein content, and other chemical interactions could all affect oxidation (Mujumdar, 2007). ANOVA (Table 3) indicate that effect of drying temperature at 50, 60 and 70 °C had significant effect on MSKO yield (P<0.05) at 5% level.

Drying of MSK was carried out at three temperatures. An increase in temperature from 50 to 70 °C resulted in a reduction in the total phenolic content of MSK. The ANOVA Table (3) reveals that the drying temperature settings at 50, 60 and 70 °C had a noteworthy influence on the total phenolic content of MSK, as indicated by a P< 0.05. Total phenolic content of MSK at drying

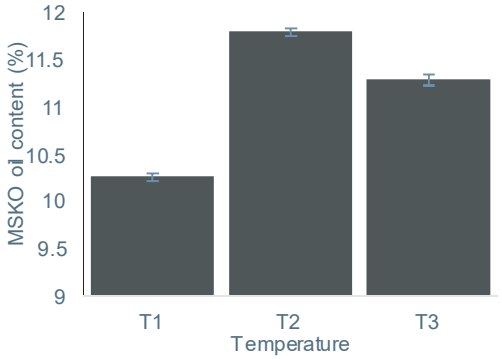

Fig. 3. Effect of drying temperatures on yield of MSKO

temperature of 50, 60 and 70 °C obtained were of 182.88±2.29 mg GAE/g, 163.24±4.10 mg GAE/g, and 96.27±3.74 mg GAE/g respectively. These results were correlated with Ekorong *et al.* (2015), Abdel-Aty *et al.* (2018).

Effect of different drying temperatures on the total phenolic content of MSK: The total phenolic content of MSK exhibited an inverse correlation with the drying temperature. The presence of total phenolic compounds in MSK displayed sensitivity to temperature, showing that they are susceptible to thermal breakdown. The phenolic elements, such as xanthones and flavonoids, in leftover mango products have a propensity to degrade when MSK is subjected to higher temperatures. This degradation of phenolic components in MSK is more pronounced at higher temperatures, likely attributed to chemical reactions, enzymatic processes, and thermal decomposition. Additionally, Dibanda *et al.* (2020) proposed that the decline in phenolic concentrations at elevated temperatures is a result of the gradual deactivation of polyphenol oxidase.

Standardization of drying process parameters: The parameters for the hot air-drying process of MSK were made consistent by considering the highest MSKO yield while retaining the maximum amount of total phenolic content in the dried MSK powder. For standardization of hot air drying of MSK completely randomized design was used and five replications were carried out. Using Design Expert 13.0.0 statistical software data was analysed and standardisation of all the fifteen runs were carried out at a point having more desirability function (Table 2).

Table 2. Variables and responses for hot air drying of mango seed kernel (MSK) experiment

Runs	Temperature (°C)	MSKO (%)	Total phenolic content (mg GAE / g)
1	50	10.32	181.25
2	50	10.22	185.57
3	60	11.85	160.34
4	50	10.24	179.89
5	50	10.27	183.53
6	60	11.75	168.56
7	70	11.25	96.56
8	70	11.34	91.27
9	60	11.78	163.78
10	70	11.37	97.32
11	70	11.29	94.91
12	60	11.81	165.52
13	60	11.83	158.23
14	50	10.30	184.23
15	70	11.23	101.58

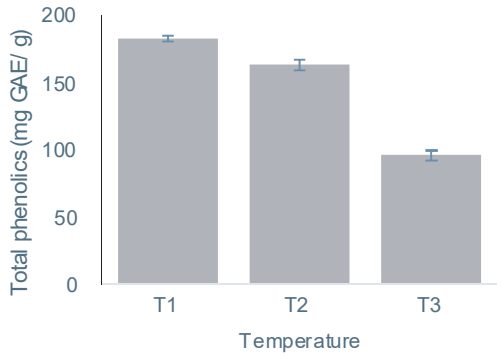

Fig. 4. Effect of drying temperatures on the total phenolic content of MSK

Biochemical composition of MSK powder: MSK powder was obtained after hot air drying of MSK at standardized solution suggested by CRD to get optimum yield of MSKO with maximum retention of total phenolic compounds. Biochemical composition of MSK powder is depicted in Table 1. These findings are consistent with the outcomes reported by (Kaur and Brar, 2017; Mutua *et al.*, 2017; Siaka, 2014; Nzikou *et al.,* 2010; Zein *et al.,* 2005; Arogba, 1997; Lasztity *et al.,* 1988).

Moisture content in MSK reduced significantly after drying of MSK. As moisture content below 5% suggests reduced chances of microbial growth, as the limited water content within the MSK hinders the proliferation of microorganisms. The MSK powder exhibited a protein content of 9.7 % indicating its richness in

Table 3. ANOVA for oil content and phenolic content variation in mango seed kernel (MSK)

Source	Oil content					Phenolic content				
	Sum of Squares	df	Mean Square	F-value	p-value	Sum of Squares	df	Mean Square	F-value	p-value
Model	6.11	2	3.05	1354.99	< 0.0001	20602.53	2	10301.27	854.97	< 0.0001
A-Temp	6.11	2	3.05	1354.99	< 0.0001	20602.53	2	10301.27	854.97	< 0.0001
Pure Error	0.0270	12	0.0023			144.58	12	12.05		
Cor Total	6.13	14				20747.12	14			

protein. Drying MSK at a standardized temperature enhances its protein quality. Moreover, the protein content in the MSK powder was observed to be higher compared to non-dried MSK due to the loss of water during drying. Implementing standardization for hot air drying of MSK resulted in a considerable increase in the fat content of MSK powder compared to MSK. The standardized drying process at a specific temperature, coupled with subsequent water loss, significantly contributed to elevating the fat content in MSK powder relative to normal MSK. The crude fiber content in MSK powder experienced an increase following the drying process, possibly due to the loss of water. Crude fiber contributes to digestive well-being, heart health, regulation of blood sugar, and the health of the colon. Yatnatti *et al.* (2014) reported that Totapuri variety of MSK powder consist of 2.20% crude fiber. Mwaurah *et al.* (2020) reported crude fiber content in MSK in the range of 0.24-4.69%. Drying leads to a rise in the ash content of MSK powder, attributed to the expulsion of moisture during the process. This concentration of ash can be attributed to the higher proportion of mineral compounds present in the dried MSK powder compared to the fresh MSK.

The carbohydrate content of MSK is enhanced as a result of hot air drying at a specific temperature, which may yield potential benefits. This rise in carbohydrates can provide a concentrated source of energy and nutrients. Moreover, the dried MSK powder, characterized by increased carbohydrate content, is adaptable for utilization in various food applications, including baking, cooking, and incorporation as an ingredient in snacks. This enhanced carbohydrate content can contribute to the overall nutritional value of products and offer a convenient and versatile option for incorporating essential nutrients into diets.

The total phenolic content within the MSK powder was determined to be 195±29.32 mg GAE per gram of MSK powder. This measurement provides valuable information about the concentration of phenolic compounds in the MSK powder. Standardizing the process of hot air drying for MSK is important for retaining the maximum amount of total phenolic compounds. Phenolic compounds can be sensitive to heat and other processing conditions, so standardizing drying methods can help to retain these compounds.

The food processing techniques, especially drying, had an influence on the overall phenolic content of mango seed kernels (MSK). Drying was shown to result in a reduction in phenolic content, and this decrease was likely attributed to the thermal degradation of these phenolic compounds (Bandyopadhyay *et al.*, 2014).

This research demonstrates that raw MSK from the Kesar variety is a rich source of beneficial phenolic compounds. Factors such as cultivar variation, extraction method, climate, agricultural practices, and drying temperature significantly impact the phenolic concentration in MSK and its powder. The study identified optimal drying conditions, showing that tray drying at 60°C is effective for producing finely powdered MSK while preserving essential bioactive compounds. MSK powder, being nutritionally rich, holds potential as a valuable functional food. Further research is needed to explore large-scale production of MSK powder products to assess their health benefits and economic viability.

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