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Physical Attributes of Different Cuts of Tomatoes during Hot Air Drying

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ABSTRACT

Different cuts of tomato, such as slices, wedges, quarters, halves, were dehydrated in a forced air drier. Effect of Inherent moisture levels (10 and 30%) in the drying tomato on the attributes such as color, texture, shrinkage and appearance was evaluated. This was done as there is a growing market preference for dried tomatoes with intermediate moisture values (10 and 30%). The variations in the moisture levels were brought about by varying the duration of drying. Duration of drying was respectively 397, 450, 850, 1310 minutes for slices, wedges, quarters and halves. Water activity was the least in slices (0.492) compared to the rest (0.655 to 0.690). Rehydration ratio of different cuts of dry tomato ranged between 15.4 and 21.5 g H_2O/10 g DM. Shrinkage in dehydrated tomato having 10% and 30% moisture ranged respectively from 14.4 to 29.2 mm and 12.9 to 28.3 mm. The color values (L, a, b,) suggest that dehydrated tomato slices had superior color appeal. Considering the different parameters that were studied the tomato slices were found to lend themselves best to dehydration in a forced air dryer when compared to other cuts.

Keywords: dehydration, physical characteristic, shape, tomato, water activity

INTRODUCTION

Sun-dried tomatoes are becoming popular in modern times throughout the world. The nutritional advantage of consuming tomatoes may be prompting this (Giovannucci 1999; Weisburger 2002; Sesso *et al.* 2003; Willcox *et al.* 2003). In developing countries where tomato is grown in abundance, most of it is processed into tomato paste and paste-based products like ketchup and sauces. Dehydration of tomato offers an appropriate and alternate approach. In India no dehydrated quality product is available on the market (Madan *et al.* 2008a). Sporadic reports on dehydration of tomatoes are available. Tomatoes cut into pieces were sun dried by Gupta and Nath (1984), air dried by convection by several workers (Tripathi and Nath 1989; Olorunda *et al.* 1990; Hawalader *et al.* 1991; Baloch *et al.* 1997; Zanoni *et al.* 1999). Trials to dry whole tomatoes have also been undertaken (Shi *et al.* 1997). Sun-dried tomatoes with very low moisture content (<5%) have lower consumer preference. When tomatoes were sun dried in Indian conditions the products were found to contain moisture levels ranging between 3.41 and 5.37% (Joshi *et al.* 2006), these were found to be too dry by habitual users. It is apparent that quality of dried tomatoes may be affected by the rate of drying and also its moisture content. Several factors are responsible for this. At the same time there is a growing market preference for dried tomatoes with intermediate moisture values (10 and 30%). The quality of drying of food samples is influenced by physical structure, chemical composition and extent of water binding within the food (Potter and Hotchkiss 1996). Thus shape and final moisture contents were two parameters that were evaluated. The effect of the final moisture level (10 and 30%) on the quality of dry tomato was also observed. Thus, a study was conducted to observe the effects of shape and inherent moisture levels in drying tomatoes on some significant physical attributes such as color, texture, shrinkage and appearance.

MATERIALS AND METHODS

Tomato fruit are classified based on the shape as globe or roma shape. Globe type tomato was used in the study. 2.5 kg of ripe medium sized tomato (mean weight 117 ± 5 g) fruits were procured from the local market. These were used for the entire study. 200 g of tomatoes were comminuted in a blender. Portions of the comminuted material were used to estimate the dry matter, total soluble solids and pH. Remaining tomatoes were cut into different shapes. Slices of uniform thickness measuring 1 cm were cut using a mechanical slicer. Halves, quarters and wedges (eight pieces per tomato) were cut manually using a sharp steel knife taking care to get uniform sized pieces. Tomatoes were cut and placed on parchment paper. 100 g of each shape was worked in triplicates. Samples were dried on wire mesh racks in a forced-air cabinet dryer at a temperature of 65°C. Because most foods are heat sensitive they are generally dried at a lower temperature, around 65°C (Siddappa 1998). All analyses were carried out in triplicate.

Mass

The mass was recorded on an electronic balance with an accuracy of ± 0.01 g. The rate of drying and duration of drying was computed using these observations.

Color measurements

Colour measurements were performed using a Minolta Chromameter tristimulus color analyzer (Model CR- 300, Minolta Camera Co. Ltd. Osaka, Japan) consisting of an 8 mm diameter measuring area with a diffuse illumination/2° viewing angle. The chromameter was calibrated against a standard white reference tile. Measurements were taken three times for each shape. Readings of fresh and dried (30 and 10% moisture levels) were recorded using the CIE or the Hunter L*a*b* scale, where L* represents lightness, a* represents chromaticity on a green (–) to red (+) axis and b* represents chromaticity on a blue (–) to yellow (+) axis (Ranganna 1986).

Received: 29 August, 2008. Accepted: 15 January, 2009.

Original Research Paper

Acidity

pH of an aliquot of representative sample of fresh tomatoes (freshly comminuted) was measured using an Acumet pH meter 25 (Fisher Scientific Co.).

Total soluble solids

Total soluble solids of an aliquot of representative sample of fresh tomatoes (freshly comminuted) were estimated using a portable refractometer (0-32°Brix) at 20°C (Ranganna 1986).

Dry matter

Dry matter content of the fresh sample was determined by taking representative triplicate samples and placing them at 105°C in an oven overnight until a stable weight was reached. The moisture content of each sample was computed (Anon 2000). Dry matter in the fresh sample was determined using the expression X=A-B where X is dry matter content in the sample taken for determination of the drying rate, A is the weight of the sample taken, and B is its moisture content (Ranganna 1986).

Relative moisture (g water/g dry matter in drying slices)

This was determined in order to calculate the rate of drying in which relative moisture content in the drying tomato was determined using the expression, g water/g dry matter = S - X/S where S is the weight of sample after equilibration and X is its dry matter content (Ranganna 1986).

Drying rate

Drying rate was computed using the model $mr = m\ e^{bx}$ (Joshi *et al.* 2008) where: mr = moisture ratio, m = model constant, b = drying rate, x = time, min.

Shrinkage

The percentage shrinkage was determined by measuring the length/diameter of fresh tomato pieces, at 30 and 10% moisture levels using calipers with gradations of 0.01 cm. Shrinkage was computed using the formula (Initial measurement – measurement at 30/10% moisture levels * 100)/Initial measurement (Joshi *et al.* 2008).

Photographs

Tomato slices were photographed using a digital camera (Canon PowerShot A310). The camera was mounted on a stand and the slices were photographed from a constant distance (30 cm). Samples were photographed when fresh, at 30 and 10% moisture levels.

Water activity

Water activity was estimated by the instrument 'Aqualab' (Decagon Devices, Inc., USA). In the 'Aqualab', a sample is placed in a sample cup which is sealed against a sensor block. Inside the sensor block is a fan, a dew point sensor, a temperature sensor and an infrared thermometer. These instruments allow the measurement of parameters leading to the computation of water activity of the sample (Anon 1999).

Rehydration ratio

Five g of dehydrated sample was submerged in boiling water and drained on a metal sieve for 5 min. Weight of the drained tomatoes was recorded. Rehydration capacity was determined by the regained moisture calculated from the sample weight difference before and after rehydration (Ranganna 1986). The dehydration measurements were conducted in triplicate for all tests and means were reported.

Statistical analysis

Analysis of variance (ANOVA) was performed using the software "XLSTAT Version 7.5.2" by Addinsoft, NY, USA, in order to test the significance of the observed differences. When the effects of treatments were significant (at P=0.05), the mean values for each parameter were compared by a multiple comparison Duncan test to look for grouping (at P=0.05).

RESULTS AND DISCUSSION

Whatever method of drying is employed, food dehydration involves getting heat into the product and getting out moisture. Operating conditions may vary. Drying of vegetables can be performed by cabinet hot air drying, funnel drying, kiln drying, belt trough drying, bin drying, fluidized bed drying, spray drying, roller drying, microwave drying, dehydro freezing, osmo air drying, etc. The choice of drier is based on several requirements (Potter and Hotchkiss 1996; Manay and Shadaksharaswamy 2001). The processing cost of vegetables during drying is less than other processing. Air convection driers have been recommended for drying pieces of food material. Constituent orientation is an important factor in dehydration of vegetables as few foods approach homogeneity at the molecular level. Physical factors affecting heat and mass transfer are temperature, humidity, air velocity, surface area and food raw material properties. Surface area is affected by sub-division and shapes to which the vegetables are cut. Smaller particles or thinner layers reduce the distance heat must travel to the centre of the food and reduce the distance through which moisture must travel to reach the surface and escape (Potter and Hotchkiss 1996). Dehydration refers to a near complete removal of water from foods under controlled conditions. In food dehydration a maximum drying rate is desirable, and so every effort is made to speed heat and mass transfer rates. Thus, vegetable pieces dried in a properly designed hot air oven in 4 h would retain greater quality than the same product sun dried over 2 days. Other more efficient methods would impact both quality of the product as well as the rate of dehydration. In the present experiment a simple hot air drier was used to assess the impact of the shape of tomato on the rate of drying. Care was taken to obtain tomatoes of uniform type based on color, firmness and size.

Description of the fruit

The fruit were fully ripe, uniform in shape and colour, round globe shaped, firm, weighed 117 ± 5 g, having a pH of 4.8 and total soluble solids of 4.2°Bx.

Drying rates

Selection of drying temperature is very important. In the case of tomato perhaps the most important quality factor is lycopene degradation. The most important contributing factor is temperature. The magnitude of lycopene destruction by increased lighting is less severe than by increased temperature (Shi and Le Maguer 2000). Thus, lower drying temperatures (65°C) are often recommended. Thus, at a drying temperature of 65°C there were no (statistical) significant differences in the drying rates due to shapes (**Fig. 1**).

Table 1 Duration of drying, re-hydration ratio and water activity of dry tomato dried in a cabinet air drier.

Dry tomato shape	Duration of drying[1] (min)	Water activity (a_w)	Rehydration ratio (g water/10 g of dry tomato)
Halves	1310.0 a	0.679 a	15.376 c
Quarters	850.0 b	0.690 a	18.399 b
Slices	396.7 c	0.492 c	21.543 a
Wedges	450.0 c	0.655 b	18.254 b

* Means in the same column with the same letter are not significantly different at the 0.05 level.

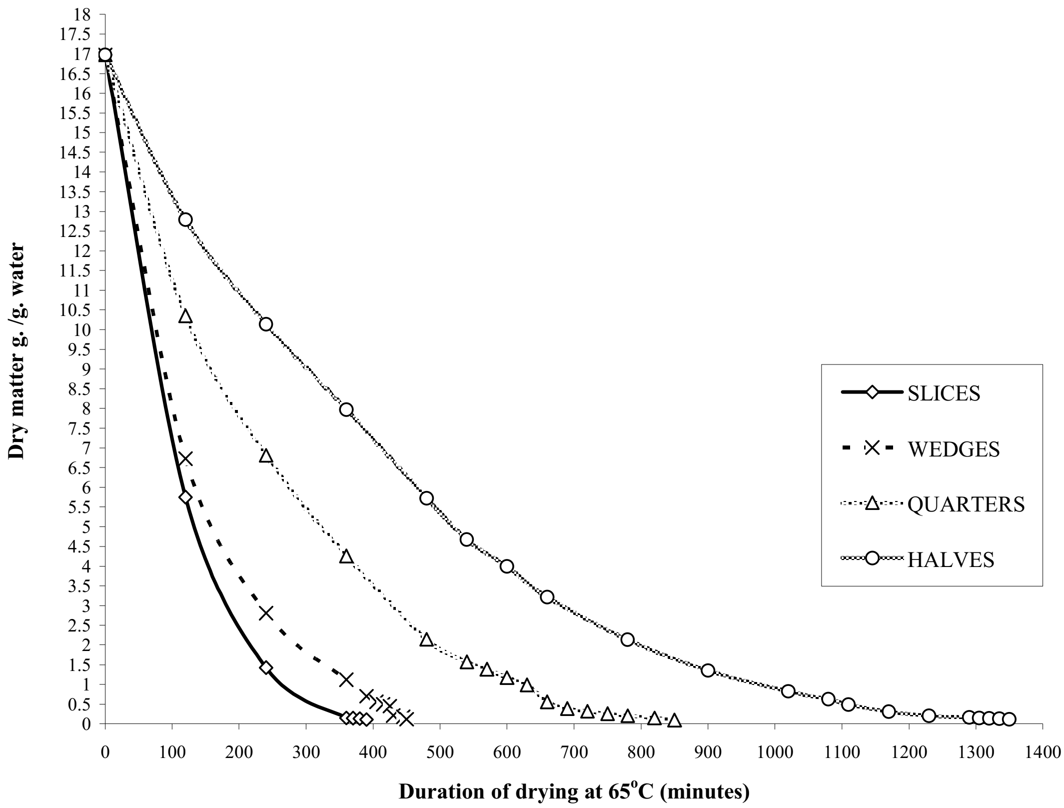

Fig. 1 Drying rate of tomato pieces of different shapes.

However, the duration to which the different shapes need to be dried to achieve the desired moisture levels – 30 and 10%, differed significantly. Halves required significantly more time than the rest; slices and wedges took the least time (**Table 1**). Variations in drying time due to shapes of tomato pieces and drying conditions have been reported by other workers. Hawlader et *al.* (1991) employed temperatures between 40 and 80°C, Shi *et al.* (1997) 95°C, Olorunda *et al.* (1990) 60–80°C and Zanoni *et al.* (1999) dried tomato halves at 80 and 110°C. Drying took from a few to over 10 h. A generalised drying curve includes a constant drying region and a falling rate region (Mujumdar 1987). Zanoni *et al.* (1999) found that the drying tomato moved quickly to the falling rate period. Madan *et al.* (2008b) observed the effect of different pretreatments on the drying rate of tomato halves. They observed that most of the drying progressed in the falling rate period and this was affected by the pre drying treatment. In the present study, slices and wedges progressed sharply into the falling rate regions when compared to quarters and halves (**Fig. 1**). Durance and Wang (2002) reported only a slight falling rate effect in vacuum microwave dried tomatoes when compared to hot-air convection dried tomatoes.

Color

Color is an important quality factor for tomato, and color measurements are often used to describe the quality of processed tomato products. Color values of processed tomato have been presented as Hunter L*, a*, b* values (Shi and Le Maguer 2000). Significant changes occur in color during the process of drying. According to Olorunda *et al.* (1990), drying time and temperature are associated positively with tissue darkening. Typically an increase in drying time and temperature results in an increase in darkness L* and a decrease in redness (a*/b* value). Kerkhofs *et al.* (2005) reported minimal changes in colour and nutrients after different cultivars of tomato were dried at a very low temperature (42°C), but for a very long duration (48 h). However, this temperature is close to sun drying. For more efficient drying higher temperatures (65°C) are practical. Coming to the present study and taking into account the 'L' values the slices were of lighter color compared to the other shapes at both end stage (30 and 10%) moisture levels. Slices and wedges of tomatoes had significantly higher 'a' values compared to halves and quarters (**Table 2**). Tripathi and Nath (1989) observed tissue darkening with increasing drying time and temperature. In the present study tomato slices took a significantly shorter time than other shapes and they exhibited lighter color, which is evident from higher L* values. The photographs of the samples as seen in **Fig. 2** also show that at 30 and 10% moisture levels slices and wedges exhibit more redness. At the 30% level 'b' values do not appear to be different. However, some differentiation occurred as drying progressed. At the 10% level, slices had higher 'b' values when compared with the rest of the shapes.

Table 2 Effect of drying on color and shrinkage of cut tomatoes (mean values#).

Shape	Shrinkage* (mm)		Colour values					
			L	a	b	L	a	b
	30%	10%	30%			10%		
Slices	20.49 b	20.44 b	54.87 a	18.68 a	21.32 a	52.99 a	19.15 a	22.79 a
Wedges	12.90 c	14.41 b	46.04 b	18.37 a	18.88 b	47.71 b	18.97 a	17.90 b
Halves	28.32 a	29.17 a	43.02 b	13.72 b	12.41 c	42.63 bc	12.41 b	12.16 c
Quarters	16.20 bc	14.50 b	42.81 b	13.03 b	15.73 c	41.45 c	12.12 b	10.81 c

Data are means of 3 replicates
Mean separation in columns by Duncan's multiple range test, P=0.05.
* Shrinkage: (initial measurement - actual measurement * 100)/Initial measurement

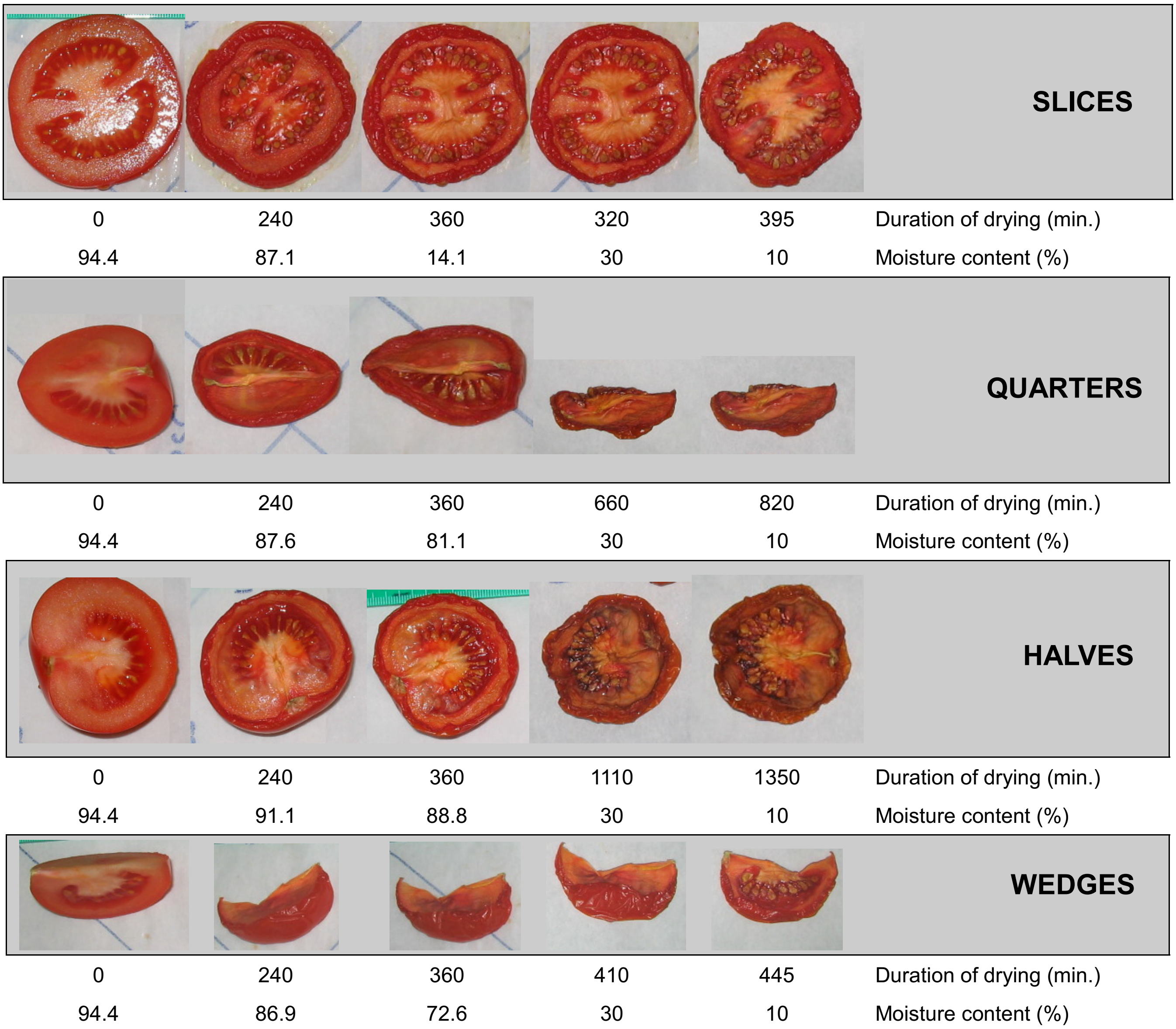

Fig. 2 Photographs of different shapes of cut tomatoes at different stages of drying and moisture levels.

This suggests that the color of slices, and to a certain extent that of wedges, was lighter and towards yellow and red which has more consumer appeal. Observing **Fig. 2** confirms this and allows the conclusion that the finished slices had a uniform and attractive color both at 30 and 10% levels compared to other cuts of tomato.

Water activity (a_w)

The water activity plays an important role in influencing non-enzymatic browning and microbial growth. Most spoilage micro organisms are inhibited in low moisture foods (a_w <0.60) (Troller and Christian 1978). According to Lewicki *et al.* (2002) water activity of dried material is dependent on the dry matter content. They reported water activity of raw and dry tomato as 0.995 and 0.322-0.777, respectively. Madan *et al.* (2008a) reported water activity values for differently pretreated dry tomato. Their water activity values ranged between 0.358 and 0.357; moisture content of these samples were also concurrently lower – 6.6 to 6.7%. A look at **Table 1** shows that there were some differences in the water activities due to the shape of the tomato pieces. In this respect slices appeared to have a really low water activity (a_w = 0.49). The other cuts can also be considered as low moisture foods as judged by their water activities.

Rehydration ratio

Rehydration is an important parameter of effective dehydration. The observations of the rehydrated material are provided in **Table 1** and expressed as g of water in 10 g of dried samples. The samples had a good rehydration capacity. The slices exhibited higher rehydration capacity compared to the other shapes that were studied. However, the values obtained were lower than what was reported by Tripathi and Nath (1989) and Madan *et al.* (2008a); their rehydration ratio values were respectively 3.5 and 3.36%. Lower values observed in this study can be partly attributed to the higher initial moisture content. While Lewicki *et al.* (2002) and Joshi *et al.* (2008) reported that the rehydration of dried tomato does get affected by pre-drying treatments. In the present study different cuts of tomato were found to marginally affect the rehydration ratio (**Table 1**). However, better rehydration characteristics were reported for vacuum microwave-dried tomatoes when compared to hot-air convection-dried tomatoes by Durance and Wang (2002). They attributed the improved rehydration in vacuum microwave-dried tomatoes to a puffed structure.

Shrinkage

Tomato halves exhibited a different pattern of shrinkage than the remaining shapes. They had the highest shrinkage at both end moisture levels. **Fig. 2** reveals a shriveled appearance. From photographs of the different shapes of tomato dried to 10 and 30% it is evident that the slices shrunk in a radial manner and uniformly, and this is more evident at the 30% moisture level. The quarters exhibited a greater shrinkage at 30 rather than 10%. Uneven thickness of quarters resulted in delayed drying of the centers. This resulted in uneven drying and curling. The curling of tomatoes reduced when tomatoes were dried to 10% moisture levels.

CONCLUSION

Duration of drying was least in slices that reached both 30 and 10% moisture levels when compared to other tomato cuts. Dried tomato slices had a uniform and attractive color both at 30 and 10% levels. Dried slices shrunk in a radial manner and uniformly especially at 30% moisture level. The percentage shrinkage was least for slices when compared to other cuts. Further, the water activity of slices was lower than all the other cuts that were tried. Among the four shapes considered, slices were found to lend themselves best to thermal drying in a forced air dryer compared to other tomato cuts.

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