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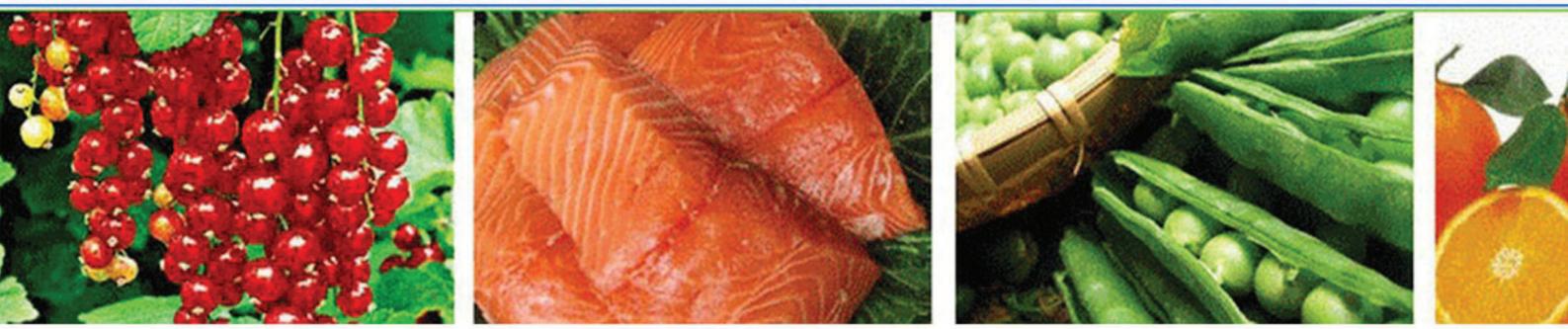

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EFFECT OF COLD STORAGE ON THE QUALITY OF MINIMALLY PROCESSED CAULIFLOWER

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ABSTRACT
Cauliflower has been described as a vegetable with a high nutritional value due to its important content of vitamins, antioxidants and anti-carcinogenic compounds. Cauliflower inflorescences are harvested while they are totally immature, which implies severe changes in nutrient, water and hormonal status. Harvesting and the following processing can cause a severe stress determining the appearance of accelerated senescence symptoms. The effects of processing and cold storage of minimally processed green cauliflower were investigated. Florets were treated with antioxidants before storage in PE bags at 4°C for 21 days. During storage, weight loss, colour, firmness, soluble solids content and pH were evaluated. Minimally processed cauliflower showed good overall quality maintenance during cold storage but also susceptibility to browning of cut zones.

1. Introduction

Vegetables are important components of the diet, supplying a multitude of health-related phytochemicals. The consumption of cruciferous vegetables has a long tradition in many countries owing to their typical taste and qualities. Among these, cauliflower (*Brassica oleracea* L. var. *botrytis* L.) is well known throughout the world and is highly appreciated for its content of vitamin C (Lee and Kader, 2000), antioxidants and anti-carcinogenic compounds like glucosinolates. These are thioglycosides, characteristic of all Brassica species, that when degradated by either enzymes within the plant or within the alimentary tract, yield secondary compounds that have been linked to a reduced risk of specific forms of cancer. (Dillard and German, 2000; van Poppel et al., 1999; Verhoeven et al., 1997).

Cauliflower is cultivated for its inflorescences that are harvested while they are totally immature. There are varieties with different sizes and colours of the inflorescences (white, green, purple), different speeds of development (cycles which run for between 80 and 240 days) and different cultivation periods (from August to May in the case of Italy). Cauliflower is mainly commercialized as a fresh vegetable, but a minor part of the production is destined to freezing or fermentation. In recent years there has been a growing interest in an 'intermediate' form of commercialized cauliflower as a minimally processed product (Sanz et al., 2007).

Demand for fresh, minimally processed vegetables has led to an increase in the quantity and variety of products available to the consumer. Fresh-cut cauliflower should be considered as a new product and thus has received very little attention in the scientific literature. Cauliflower can be marketed cut in florets and packed in small units overwrapped with an appropriate film to avoid excessive

dehydration and the generation of inadequate atmospheres. This product must also be kept under refrigeration during marketing in order to maintain its quality and enhance its shelf life.

Quality and shelf-life of minimally processed vegetables may be affected by pre-harvest (Miceli and Miceli, 2014; Settanni et al, 2012; Settanni et al, 2013) or post-harvest (Miceli et al., 2014) factors, thus raw material quality, post-harvest treatments, packaging and storage conditions can greatly affect consumer acceptance and produce marketability.

The aim of the present work was to investigate the effect of processing and cold storage on minimally processed green cauliflower.

2. Materials and methods

Green cauliflower plants (*Brassica oleracea* L. var. *botrytis* L., 'Emaraude F1') were grown in the south-west coastal area of Sicily during autumn. Plants were selected for high quality and absence of defects. Curds were harvested in the second half of December and directly transported from the field to the laboratory. The cauliflower inflorescences were processed after manual removal of outer leaves by cutting into florets of 30-60 g each. Then they were washed by immersion for 5 min in tap water (added with 100 ppm free chlorine), rinsed to lower the free chlorine and finally dipped in a 1% citric acid solution for 5 min. Florets were drained and centrifuged using a handheld salad spinner to remove excess water and samples of 350 g were immediately placed in PE bags, sealed and stored at 4°C for 21 days. Immediately after processing and after 7, 14 and 21 days of storage, samples were randomly taken to evaluate the quality of minimally processed green cauliflower. Weight loss was evaluated by weighing samples soon after processing and during storage. The results were expressed as grams per 100 g of initial fresh weight.

Superficial colour of the top of the florets and of the cut zones was determined with a Colorimeter (Chroma Meter CR-400C, Minolta, Osaka, Japan), by measuring parameters L*, a* and b* at nine points on the florets and five point for the cut zone of each sample and storage time. Hue angle (h°) and Chroma (C*) was calculated as $h° = \arctan(b^*/a^*)$ when $a^* > 0$ and $b^* > 0$, or as $h° = 180° + \arctan(b^*/a^*)$ when $a^* < 0$ and $b > 0$ (McGuire, 1992) and $C^* = (a^{*2} + b^{*2})^{1/2}$.

Firmness was measured using a digital penetrometer (model 53205, TR Snc., Italy) with a 6 mm diameter stainless steel cylinder probe, in the cut zone of the stalk of 4 florets and in 6 points of the upper part for each sample.

Overall appearance was evaluated by an informal panel made of nine people (4 men and 5 women, aged 35-55) using a 1 to 5 scale, with 5 = excellent or having a freshly harvested appearance (e.g. green curds with no yellowing or riciness, free from handling defects and disease), 3 = fair/limit of marketability (e.g. some browning of the curds or the stalks, presence of minor defects or disease), and 1 = poor /unmarketable, with dark brown curds or stalks, and major defects and disease.

Samples of 150 g were then juiced with a commercial home juicer. The extract was centrifuged at 5000 rpm for 10 min and supernatant used to determine soluble solids content (SSC) and pH using respectively a digital refractometer (MTD-045nD, Three-In-One Enterprises Co., Ltd., Taiwan) and a digital pH-meter (waterproof pHTestr 30, Eutech Instruments, Nijkerk, The Netherlands).

All determinations were carried out in triplicate. Statistical analysis was performed using ANOVA and the means were separated using Duncan's Multiple Range Test.

3. Results and discussions

Minimally processed cauliflower was stored during 3 weeks at 4°C. During storage weight loss was very low and did not overcome 1% (table 1). This might be due to the low permeability to water vapour of the PE bags used for packaging, as found by Olarte et al. (2009) and Sanz et al. (2007) for broccoli and cauliflower.

Colour is one of the most important aspect in sensory evaluation. The surface colour of florets slightly changed after one week of storage and then remained stable for the other two weeks (table 2). Lightness value L* (represented by 0 = black and 100 = white) showed slight negative variations after 7 days with no other significant changes up to day 21. Coordinate a* decreased while coordinate b* increased after the first week of storage. The decrease of a* toward green indicates that there was no browning of the samples; the increase of b* indicates a yellowing of the samples. From these coordinates, Hue angle was calculated (90° = yellow and 180° = green). Florets showed initial Hue values of about 161 and did not significantly change after 21 days of storage. Chroma is a measure of colour purity or vividness. Chroma values significantly increased between days 0 and 7, after which levelled off. The stability of colour parameters of floret surface during cold storage of minimally processed green cauliflower may be due to a low variation of the contents of vitamin C, β-carotene and chlorophyll (Paradis et al., 1995). The colour of cut zones showed greater changes during cold storage. L* value decreased significantly after 7 d of storage and dropped continuously till the end of the storage period ($\Delta L_{0\text{-}21}$=16.2). The browning of cut zones was also evident in Chroma and Hue angle variations: colour saturation increased significantly during storage, while Hue angle values showed a progressive decrease until 14 days of storage.

Even though cauliflower is generally eaten cooked, the firmness of raw cauliflower is a good attribute of quality. It is related with curd compactness that decreases as inflorescence develops toward flowering. This modification can reduce shelf life and consumer acceptance of fresh or minimally processed cauliflower, as it is a good indicator of freshness or deterioration. The firmness of the upper part of curds before packaging was 37.6 N (table 1). During storage, this value slightly reduced and was statistically different only after 14 days of storage with no further change. Cold storage caused also a small but significant decrease of stalk hardness after 7 days of storage to a level maintained till the end of storage period.

During post-harvest the level of sugars of vegetables usually decreases since they are consumed by respiration while the supply of sugars from the plant is interrupted (Lemoine et al., 2009), nevertheless, soluble solids content (SSC) of minimally processed green cauliflower did not significantly varied during cold storage (table 1) as also found by Hodges et al. (2006).

The pH value of cauliflower (6.32 before packaging) slightly increased during the first 7 days of storage, after which no other changes occurred (table 1). This increase could be explained by the tissular breakdown that the vegetables undergo during storage; nevertheless, in the case of minimally processed vegetables, the capacity to respond physiologically is retained and cushions the variations in pH induced by the high levels of CO_2 which build up in the atmosphere inside the packs (Olarte et al., 2009).

Scores for overall appearance decreased slowly during storage (table 1). Florets maintained the highest score for the first week of storage. The attribute which suffered most during the second part of storage was the colour (browning) of the cut zones. This alteration of colour determined a reduction in overall appearance score (2.7) and negatively affected the marketability of minimally processed cauliflower at the end of the trial.

4. Conclusions

Cold storage is one of the most common technologies used to delay senescence, decay and quality loss during post-harvest life of vegetables. Fresh-cut vegetables suffer a severe processing stress that may greatly alter the physiology of tissues compared to intact organs (Lemoine et al., 2009). Thus, also minimally processed vegetables benefit of cold storage in order to keep quality throughout shelf life.

Green cauliflower showed to be suitable for processing as a minimally processed vegetable. Minimally processed green

cauliflower maintained a good firmness and sensory quality till 2 weeks of storage at 4°C.

Limitation of shelf life was due mainly to the browning occurred in the cut zones. The reduction of the colour alterations in the stalks may lead to prolong shelf life over 3 weeks.

Table 1. Influence of the storage at 4°C on quality parameters of minimally processed cauliflower.

Days at 4°C	Weight loss (%)	Firmness (N)		SSC (°Brix)	pH	Overall Quality
		Top	Stalk			
0		37.6a	66.8a	6.6	6.32b	5.0a
7	0.5b	35.1ab	63.3b	6.8	6.62a	4.8a
14	0.5b	33.1b	62.7b	6.5	6.58a	4.2b
21	0.8a	33.1b	61.3b	6.6	6.56a	2.7c

Data within a column followed by the same letter are not significantly different according to Duncan's multiple range test (P<0.05).

Table 2. Colour changes of floret tops and cut zones during storage at 4°C.

Days at 4°C	L*	a*	b*	Chroma	Hue angle
Floret top surface					
0	69.8a	-17.0a	50.0b	52.8b	161.3
7	65.6b	-20.3b	57.7a	61.2a	160.6
14	64.9b	-20.2b	57.1a	60.5a	160.6
21	64.1b	-19.0b	55.4a	58.5a	161.1
Cut zone					
0	80.8a	-3.9c	14.8c	15.3c	104.8a
7	70.7b	-2.7b	17.9b	18.1b	98.6b
14	68.3bc	-0.6a	20.6a	20.6a	91.7c
21	64.8c	-0.3a	22.5a	22.5a	90.8c

Data within a column followed by the same letter are not significantly different according to Duncan's multiple range test (P<0.05).

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