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Storage environment/packaging materials impacting bread spoilage under ambient conditions: A comparative analysis

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A B S T R A C T

Packaging in bread-making industry is one of priorities to satisfy the peculiar requirements of freshness in bread. A suitable packaging material allows for both rapid heat exchange with the environment and water vapour evaporation in order to prevent condensation inside the bread package. The effectiveness of some storage media/packaging materials in preventing bread spoilage under ambient temperature was studied. Bread staling, microbiological stability and organoleptic changes were evaluated as a function of storage time. The functional properties (water and oil absorption capacities and water oil absorption indices) of the bread were estimated .The water absorption capacity (WAC) of bread was in the range of 144-221 g/100 g sample, while the oil absorption capacity (OAC) range was 113-132 g/100 g. Water Oil Absorption Capacity (WOAI) for each of the packaging materials was < 2.0, which indicates the lipophilic nature. All the bread slices stored under different media/packaging materials, except perforated bowl and transparent plastic bowl exhibited sensory scores of 2.5 and above. Microbial growth manifested in bread kept in perforated and transparent plastic containers compared to the bread kept in cellophane and aluminum plate. This study clearly shows differences in the rates of staling, microbial stability and physical/chemical changes at different storage conditions.

Capsule Summary: Differences in the rates of staling, microbial stability and physical/chemical changes at different storage conditions of bread using different packaging materials was studied and it was observed that Common Cellophane Bread bag, proved to be the best packaging material.

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INTRODUCTION

Bread is a major wheat-based product which has gained customers' acceptance world-wide. It is commonly consumed as a convenience food and this transverses all populations, rich and poor, rural or urban (Badifu et al., 2005). The main quality attributes of bread are colour/appearance, texture and taste. However, the major problem associated with bread and other bakery products is their relative short shelf life.

Certain physical and chemical changes affecting bread crust and crumb occur during their storage (He and Hoseney, 1990). Bread suffers from two major spoilage mechanisms, namely staling and microbial deterioration. Each of them alters bread's stability and its eating qualities (Bartkiene et al., 2018; Debonne et al., 2020; Garcia et al., 2019; Mantzourani et al., 2014; Quattrini et al., 2019; Valerio et al., 2008; Valerio et al., 2015).

Packaging materials are great determinants of microbial growth on bread (Nurcan et al., 2011). It is known that cereal-based products are commonly affected by moulds. Colours of bread moulds go from white to golden and to dark green. Contamination with mould spores happens at the end of baking process when the spore-contaminated objects including human hands, clothing or bread slicing machine have contact with bread post- processing. Staling has been defined as "almost any change, short of post-baking period, making it less acceptable to the consumer" (Zobel and Kulp, 1996). Changes that occur in bread during storage include among others the increase in the crumbliness of the crumb, loss of crust crispiness, increase in the hardness of the crumb, sensory changes in taste, mouth feel and aroma, increased opacity of the crumb, decreased water absorption capacity of the crumb, susceptibility to attack by alpha-amylase and decreased soluble starch content (Hertz, 1965). The major changes that occur in baking are moisture redistribution, retro-gradation, increased bread firmness associated with loss of flavor and aroma (Galic et al., 2009). Bread may be cooled for 1hour and thereafter packaged and may be considered fresh for up to 8 hours after which staling begins. In 24 hours bread is still acceptable but beyond this period, it tends to become stale (Katina, 2005).

Studies showed that bread may remain fresh if stored at temperature above 60°C or below 10°C. The staling rate had been reported to increase as temperature decreased from 60°C and reached a maximum at -2°C (Katz, 1928). This report showed that staling process had a negative temperature co-efficient. High moisture barriers such as films, plastic or glass containers, aluminum with lids, paper wrappers or boards are agents that have been used to prevent moisture loss from materials to the atmosphere. In particular, high moisture proof films have often been used to prevent moisture loss from bread crust to or moisture gain from the atmosphere that could make the crust soft and leathery. Staling makes bread crust less elastic, dry and harsh with changes in aroma and flavor. The chemicals that have been used to prevent or delay staling include lipids or shortening, flour protein, yeast levels, amylolytic enzymes, emulsifiers and surfactants. The lipids associated with bread baking is divided into two, those occurring naturally within the flour (free and bound) and added sweetening to bread formula. It is generally acknowledged that fats (whether chemical or plant vegetable) improve the keeping quality of breads apparently by reducing the ratio of firming, the method by which they impact this effect is not well known.

In bread dough, surfactants form helical complex with amylase before gelatinization takes place causing crumb softening action. This reaction immobilizes the amylase within the starch granules and prevents it from leaching out (retrograding) and forming a gel structure (Ghiasi et al., 1982). Other factors are time and temperature of storage. The work was designed to evaluate changes in the physico-chemical, organoleptic and microbial properties of bread without packaging material and bread stored in selected packaging materials under ambient conditions.

MATERIAL AND METHODS

Material and sample collection

Bread samples were procured from a reliable source in South West Nigeria noted for producing bread to International standard. Different packaging materials were also used which were: Transparent plastic container with cover (1000 mL), Common cellophane bread bag (in this locality) (980 mL), Aluminum foil plate with cover (740 mL) and Perforated basket with cover (1000 mL). All materials were sourced locally.

Analytical procedures

Physico-chemical properties of bread: Baked bread was cooled for 1hour after removal from oven, and was sliced into (2x3x5) sizes. The bread sizes were distributed into different storage media for microbiological and physico-chemical changes over a period of time, during which staling and storage were overt.

Water and oil absorption capacity: The water and oil absorption capacities of fresh bread and bread samples withdrawn from different packaging materials/media were carried out by the method of Agunbiade and Longe (1996). The resulting water absorption capacity (WAC), calculated as gram water absorbed per gram sample, is a measure of the extent to which the sample is capable of absorbing and retaining water within its matrix under a defined condition. The weight of the oil absorbed and retained/gram sample (OAC) was obtained by multiplying the weight of oil absorbed by 0.929, the specific gravity of oil used.

Water-Oil-Absorption Index (WOAI): The water –oil-absorption index was determined, using the method of De Kanterewiz et al., 1987 whereby it was computed as the ratio of WAC to OAC.

Microbial assays

Total yeast cells and fungi in bread samples were determined by the Standard Methods for the Examination of Water and Wastewater, 20th Edition (1998) American Public Health Association. Coliforms were determined by the method of Woshsen et al. (2008)

Sensory evaluation

Table 1: Changes in the physico-chemical characteristics of bread slices stored in different packaging materials at room temperature

Time	Control			Packing materials								
				Cellophane Bag (CCB)			Aluminum Plastic Plate (ALP)			Perforated Plastic Bag (PPB)		
	WAC	OAC	WOAI	WAC	OAC	WOAI	WAC	OAC	WOAI	WAC	OAC	WOAI
24 h	194.9 ±32	116.7 ±22	1.67	194.4 ±54	123.4 ±32	1.57	167.4 ±32	126.2 ±33	1.32	198.6 ±15	121.8 ±16	1.63
48 h	170.7 ±21	127.5 ±32	1.33	187.9 ±27	130.4 ±26	1.43	160.6 ±21	130.0 ±45	1.23	201.0 ±22	123.7 ±14	1.63
72 h	177.3 ±11	134.8 ±33	1.32	167.8 ±25	127.6 ±27	1.31	158.8 ±41	136.5 ±19	1.16	217.1 ±13	130.3 ±19	1.66
96 h	187.6 ±31	145.7 ±20	1.28	164.0 ±39	126.7 ±11	1.30	144.7 ±12	138.8 ±29	1.04	221.9 ±21	132.1 ±20	1.68
FB	201.5 ±25	154.4 ±16	1.30									

WAC = Water Absorption Capacity, OAC= Oil Absorption Capacity, WOAI = Water-Oil Absorption Index, FB = Fresh Bread PPB = Perforated Plastic Bowl (remove)

Hedonic Rating Scale of Bread Samples: Sensory evaluation of fresh bread and bread samples withdrawn from storage media were carried out. They were all assessed for taste, colour, odour and mouth feel on 5-point hedonic scale. Baked bread was cooled for 1hour after removal from the oven and sliced into (2 x 3 x 5) sizes. The slices were distributed into different packaging materials under ambient storage for a week. Sensory evaluation was performed using randomly selected panel of judges. The panelists were instructed to evaluate bread slices in different storage media compared to fresh bread for changes in appearance, taste smell and softness using A 5-point hedonic rating scale whereby 5 = excellent, 4 = good, 3 = fair, 2 = fairly poor, 1 = poor. Fresh bread was used as standard every successive day throughout the experiment. The highest hedonic score was 5.0. This exercise was repeated three times to ensure reliability of results. The panel members were instructed to compare sensory characteristics of fresh bread with those stored at room temperature, throughout the period. Panel mean scores were recorded and subjected to ANOVA and Duncan multiple range tests using SPSS package.

RESULTS AND DISCUSSION

Table 1 shows the changes in the physico-chemical characteristics of bread slices under ambient storage in different packaging materials at 24-hourly intervals. The bread slices, packaged in transparent plastic bowl manifested haphazard decline in WAC values from day to day. Bread slices packaged in the Common cellophane bread bag (CCB) and in aluminum plate covered with lids consistently exhibited decreased WAC values in contrast to increased WAC values displayed by bread in perforated plastic bowl (PPB) as study period advanced. OAC progressively increased in bread packaged in transparent plastic bowl (TPB), aluminum plate (ALP) and perforated plastic bowl (PPB) from day one to day four. Bread slices kept in common cellophane bag (CCB) exhibited non-consistent gradient increase in OAC values as decline was observable after an initial increase in 48 hours. It was observed that WAC and OAC values (201.5±25 and 154.4±16 respectively of fresh bread (control) were higher than the corresponding values of bread in the different packaging materials. WAC: OAC ratios (WOAI) in all packaging materials were below 2.0.

Table 2 shows changes in organoleptic properties of bread slices in packaging materials at 24-hourly intervals at ambient temperature. There was a general decline in organoleptic properties of bread in each storage medium as storage progressed at ambient temperature. The bread packaged in transparent bowl, common cellophane bread bag and aluminum plate displayed sensory scores above 2.5 in the first three days. In 96 hours only bread stored in common cellophane bread bag retained acceptable sensory scores above 2.5 being 4.0 and 3.0 for appearance and smell respectively. Others were below 2.5 sensory score, the minimum acceptable value. Right from day 1 bread slices kept under perforated plastic bowl, except for their smell in 24 and 48 hours of storage period, exhibited unacceptable sensory scores less than 2.5.

Table 3 shows the Mycotal results. Progressive increase in fungal and yeast growth as storage time advanced was apparent in each packaging material. Generally, bread stored in perforated plastic bowls was observed to have the lowest fungal and yeast growth at those hours of incubation. This work examined the effect of packaging materials on bread alongside the exhibition of physico-chemical, organoleptic and microbiological characteristics of bread under ambient storage. High water Absorption capacity (WAC) has been found to be enhanced by previous baking treatment of bread slices just as gelatinization and roasting were to starch and 'garri'

Table 2: Hedonic rating scale report on bread stored in different packaging materials at room temperature

Period/duration (hours)	Parameter used	Fresh Bread (FB)	Cellophane Bag (CCB)	Aluminum Foil (ALP)	Transparent Plastic Bowl (TPB)	Perforated Plastic Bowl (PPB)
24	Appearance	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	4.67 ± 0.57^{a}	4.33 ± 0.57^{a}	1.00 ± 0.0^{b}
	Smell	5.0 ± 0.0^{a}	5.0 ± 0.0^{a}	4.33 ± 0.57^{a}	3.67 ± 0.57^{b}	3.67 ± 0.57^{b}
	Taste	5.0 ± 0.0^{a}	4.67 ± 0.57^{a}	4.67 ± 0.0^{a}	4.67 ± 0.57^{a}	1.00 ± 0.0^{b}
	Softness	5.0 ± 0.0^{a}	4.67 ± 0.57^{a}	4.67 ± 0.0^{a}	4.67 ± 0.57^{a}	1.00 ± 0.0^{b}
48	Appearance	5.0 ± 0.0^{a}	4.67 ± 0.0^{a}	4.67 ± 0.0^{a}	3.33 ± 0.57^{b}	1.00 ± 0.0^{c}
	Smell	5.0 ± 0.0^{a}	4.67 ± 0.57^{a}	3.67 ± 0.0^{b}	3.67 ± 0.57^{b}	2.67 ± 0.0^{c}
	Taste	5.0 ± 0.0^{a}	4.0 ± 0.57^{b}	3.67 ± 0.57^{b}	4.33 ± 0.0^{b}	1.00 ± 0.0^{c}
	Softness	5.0 ± 0.0^{a}	4.13 ± 0.0^{b}	4.00 ± 0.57^{b}	4.00 ± 0.0^{b}	1.00 ± 0.0^{c}
72	Appearance	5.0 ± 0.0^{a}	4.0 ± 0.57^{b}	3.67 ± 0.0^{b}	2.67 ± 0.57^{c}	1.00 ± 0.0^{d}
	Smell	5.0 ± 0.0^{a}	4.0 ± 0.57^{b}	2.67 ± 0.57^{c}	2.67 ± 0.00^{c}	1.67 ± 0.0^{d}
	Taste	5.0 ± 0.0^{a}	3.33 ± 0.57^{b}	3.33 ± 0.57^{b}	3.67 ± 0.57^{b}	1.00 ± 0.0^{c}
	Softness	5.0 ± 0.0^{a}	4.0 ± 0.57^{b}	3.33 ± 0.57^{b}	3.33 ± 0.0^{b}	1.00 ± 0.0^{c}
96	Appearance	5.0 ± 0.0^{a}	4.0 ± 0.57^{b}	2.00 ± 0.0^{c}	2.00 ± 0.0^{c}	1.00 ± 0.0^{d}
	Smell	5.0 ± 0.0^{a}	3.0 ± 0.0^{b}	2.33 ± 0.57^{bc}	1.63 ± 0.57^{c}	1.67 ± 0.0^{c}
	Taste	5.0 ± 0.0^{a}	2.0 ± 0.57^{b}	1.67 ± 0.0^{bc}	1.67 ± 0.57^{bc}	1.00 ± 0.0^{c}
	Softness	5.0 ± 0.0^{a}	2.33 ± 0.0^{b}	2.33 ± 0.0^{bc}	1.67 ± 0.00^{c}	1.00 ± 0.0^{c}

Results are means ± standard error (SE) determination. Scores differently superscripted are significantly $P < 0.05$ different

respectively (Agunbiade and Longe, 1996 and 1999). The ratio of water absorption capacity to oil absorption capacity is an index showing that all bread slices under storage gave values less than 2.0 and therefore displaying lipophilic property. There was generally a decline in organoleptic properties of bread slices at ambient temperature as storage time advanced.

The organoleptic properties of bread slices in Common Cellophane Bread Bag (CCB), Aluminium Foil (ALP) and Transparent Plastic Bowl (TPB) were highly acceptable up to 48 hrs of storage for exhibiting sensory score of 2.5 and above. In 72 h, distinct decline in the smell of bread slices kept in ALP and TPB was indicative of being significantly ($P < 0.05$) poorer than bread kept in CCB. The CCB proved to be the best packaging materials compared to others. This is because the bread kept in it exhibited significantly ($P < 0.05$) better sensory scores/results than other packaging materials in their ability to preserve the integrity of bread under ambient temperature. Perforated Plastic Bowl (PPB) is not a good packaging material. Rather it simply prevented bread not wrapped with any film, from pest infestation during experimental period.

Under micro environment such as CCB, ALP moisture accumulation may encourage the growth of yeast and fungi. Microorganisms especially bacteria and fungi have been studied to be the most abundant organisms in nature. This is due to a lot of factors among them is their small requirement for feeding and ability to produce capsules or spores to withstand adverse conditions. Furthermore, studies have showed that that not all bacteria will produce capsules or spores but most fungal/yeast cells possess characteristics that make them resist tougher adverse conditions (especially dryness and heat). Like higher organisms, ability of fungi to grow on a substrate will lead to excretion of by-products, which may be poisonous (mycotoxins) or non-poisonous but destructive by rendering spoilage symptoms, of taste, strange colour, off odour and wither (USDA, 2017).

Table 3 shows that the study of fungal growth was on the increase in all packaging materials used as the period of incubation increased. The rate of growth was lowest in the PPB, perhaps as a result of ratio of bread surface area to the surrounding atmospheric air leading to loss of moisture and reduced microbial growth. Remarkable crumb crumbliness and off odour were also more profoundly observed in PPB. This was correspondingly supported by increase in wet and presence of observable moisture in those other storage media which might have apparently encouraged the heavy fungal growth.

Fungi and yeast in bread growth may be due to human error, bread handlers before purchase, equipment used especially for slicing. Under normal conditions fungal and yeast growth should not be too high. The surface area of bread under PPB was wide which may lead to gain or loss in moisture, depending on the humidity of the immediate environment. The result here has not proved the packaging materials, (even CCB), to be good limiting factor for fungi and yeast growth. Results revealed that the recontamination of freshly produced bread can occur during the cooling, slicing, packaging step and during storage, which need to be controlled by proper packing and chemical preservatives (the use of antifungal compounds) that can help to extend the shelf life of beard during storage to avoid spoilage (Bartkiene et al., 2018; Bernardi et al., 2019; Debonne et al., 2020; Dijksterhuis, 2017; Garcia et al., 2019; Pinilla et al., 2019; Quattrini et al., 2019; Rusinek et al., 2020; Snyder et al., 2019; Vasileva et al., 2018).

Table 3: Microbial load on bread stored in different packaging materials

PC/time (h)	24			48			72			96		
	Fungi	Yeast	Total	Fungi	Yeast	Total	Fungi	Yeast	Total	Fungi	Yeast	Total
TPB	9	11	20	28	34	52	38	41	79	54	63	117
ALP	8	11	19	19	30	49	32	38	70	46	43	89
PPB	8	5	13	23	17	40	25	39	64	25	39	64
CCB	10	12	22	16	25	41	40	37	77	50	49	99
Sub-total	35	39	74	86	106	192	135	155	290	175	194	369

PC = Packaging Materials, TPB = Transparent plastic bowl, ALP= Aluminum foil, PPB= Perforated plastic bowl, CCB= Common cellophane bag

CONCLUSIONS

It has been shown that the maximum time that bread can stay and still remain consumable, under tropical condition, is 72 hours on the basis of its physico-chemical, organoleptic and microbiological parameters. Detection of relatively high levels of yeast cells and fungi in food samples may present a risk to consumers' health. Yeast and fungal levels are important for spoilage and visual monitoring in food, therefore more work needs to be done in terms of bread handling and post processing. Meticulous attention must be paid to the cleanliness of bakery workers involved in the removal of bread loaves from the bread pans and their packaging in order to reduce to the barest minimum contamination of bread loaves via their clothing, hair, nails and skin. It is recommended that measures be taken seriously towards this. If analysis is randomly carried out on most bakery products, especially the famous bread sold and found almost everywhere on our streets, we will be so amazed about the likely hazards the food we eat daily constitute. It is suggested that a statutory, independent and science-based body dedicated to protecting public health and consumers' interest in the area of food safety and hygiene be established. It will go a long way in taking reasonable steps to ensure that food distributed or marketed in Nigeria meets the highest standards of food safety.

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