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Safe storage of Egyptian Wheat Grain Using Different Types of Hermetic Poly-Ethylene Bags

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ABESTRACT

The current study was carried out to minimize the Egyptian wheat grain losses in quantity and deterioration of quality during open field storage by innovative and economic method. This method based on efficient control of moisture, moulds & insects in wheat grains during storage in three different types of poly-ethylene bags with different materials structure and film thicknesses of 90, 120 and 140 microns. The developed bags were compared with the traditional burlap storage bags. Freshly harvested wheat grain variety (Gemmiza-9) was used for the experimental work. The wheat samples were harvested from the Experimental Farm of the Rice Mechanization Center (R.M.C) at Meet El-Dyba, Kafr El-Sheikh governorate during (2014-2015) wheat harvesting seasons. Quality changes of wheat grain stored in different types of bags were measured to assess the most proper type of bags for large scale storage process. The results show that: Storing wheat grain in storage bags (Type 2 and 3) did not create a lethal environment for insects, molds and total microbial load.Wheat grain at (M.C less than 13% w.b.) could be stored in the developed plastic bags (Type 2 and 3) for more than six months without losing the grain quality and also without fumigation process for insect control. Poly-Eythelene bags (type 3) give more moisture sealing and less permeability for CO_2 in comparison with other types of bags and thereby it can safely store the grain for longer storage duration.Further tests for both storage bags Type 2 and 3 are recommended to assure larger scale storage and longer storage time.
Keywords: Wheat grain, traditional burlap bags Hermetic storage bags, grain quality.

INTRODUCTION

Wheat grain (Triticum aestivum vulgare L.) is one of the most important grain crop in Egypt. The total cultivated area of wheat in Egypt reached about 3 million Fadden and the total production exceeded 9.279 million tons with an average of 6.511 t/ha. (FAO, 2017).

Wheat grain represents almost 10 percent of the total value of agricultural production and about 20 percent of all agricultural imports. Egypt is also the world's biggest wheat importer and the GASC (General Authority for Supply Commodities) alone is the world's biggest wheat purchaser. It is thus understandable that wheat grain is a product of utter importance to Egypt and wheat grain policy is a priority for the government.

The majority of government storage is in a system of traditional flat storage called (Shona). This basic system of storage in the shona is extremely wasteful. The burlap bags often tear and leave the wheat vulnerable to weather and pests. This results in high percentage of losses of wheat and reduces its quality. While there are no official estimates available of the quantitative losses at the Shona, these are believed to be in the range of 10-20 %.

Organic-Hermetic storage or "hermetic storage" consists of a sealed storage system containing a modified atmosphere. This means that as a result of respiration effects there generally develops a very low Oxygen (O2), high Carbon Dioxide (CO2). The low permeability poly-ethylene bags maintains a constant moisture environment. Pioneering modern hermetic storage has resulted in the broad use of safe, pesticide-free hermetic storage suitable for many commodities and seeds, particularly in hot, humid climate (Navarro *et al*.,2002; Villers *et al*., 2008).

Modified atmosphere created inside the bags may offer an alternative to fumigation to control stored product insects and mold growth during storage. Past studies have clearly shown that treatments based on reduced oxygen and high carbon dioxide contents are technically suitable to control arthropod pests in durable commodities (Adler *et al*. 2000; Navarro 2006).

The current vertical steel silos capacities' can't encompass more than 20% of the country's wheat crop. The other 80 % is stored in open sites. Development of well controlled storage sites with new types of storage bags will lower storage losses to the minimum and keep the grain quality from deterioration.

The present study aims at minimizing the Egyptian wheat grain loss in quantity and deterioration of quality during open field storage by innovative and economic method. This method based on efficient control of moisture, moulds & insects in wheat grains before storage through storing the freshly harvested wheat grain in different types of poly-ethylene bags and compared with the traditional burlap storage system.

MATERIALS AND METHODS

Materials:

Freshly harvested wheat grain variety (Gemmiza-9) was used for the experimental work. The wheat samples were harvested from the experimental farm of the Rice Mechanization Center (R.M.C) at Meet El-Dyba, Kafr El-Sheikh governorate during (2014-2015) wheat harvesting seasons. The experimental work included evaluation of quality changes of wheat grain stored in different types of extruded poly-ethylene bags at laboratory scale level to assess the most proper types of bags for pilot scale storage process.

Equipment and Test Procedure:

Testing condition for different types of multi-layer poly- ethylene bags:

Three different types of barriers films were developed in cooperation with a local company (Shuman Co.). The materials specifications of the barrier films were assessed in the laboratory of the company as shown in tables (1 through 3). To assess the most proper film for wheat storage, the developed films were formed into a shape of bags with capacity of 50 kg/bag. The produced bags were filled by wheat grain at initial moisture content of 12.60% w.b and stored inside storage chamber as shown in fig. (1). The evaluation basis for wheat grain stored in the developed bags included, CO2 concentration (%), grain moisture content (% w.b), germination percentage, fungal colony count (cfu/g), total microbial count (cfu/g), insect count (insect/kg), protein content (% d.b) and falling number (sec).

Experimental procedure for laboratory scale storage of wheat grain:

- Collect the required amount of grain for storage and prepare the store for storage process.
- Fill the wheat grain in different types of developed multi-layer poly-ethylene bags at capacity of 50 kg/bag.
- Install the filled bags over wooden bars in four stocks (Three stocks represent different types of plastic bags and the fourth stock represents the traditional storage in burlap bags).
- Insert the sensor of the temperature meter inside three bags of each stock represents top, middle and bottom positions of the stored grain. .
- Take samples from each experimental stock for moisture content measurement, fungal count, insect count and other quality changes at 15 days intervals

Table 1. Specifications of the developed barrier film (type 1) 90 micron

Property		Unit	Method	Value		
				Max.	Min.	Mean
Average thickness		µm	DIN 53370	90.9	89.1	90
2 SEGMA thickness tolerance		%		4.5	2.9	3.7
Width		mm	Internal	422	422	422
Coefficient of	out/out	-------	ASTM D	0.40	0.36	0.38
friction	IN/IN		1894	0.20	0.18	0.19
	NTR/M		ISO 8295	-	-	-
Surface tension		Dyn/CM	DNI ISO 8296	-	38	-
Tensile strength at break MD		Mpa	ASTM D882	45.1	36.1	40.5
Tensile strength at break TD		Mpa		38.1	36.7	37.4
Tensile strength at yield MD		Mpa		16.7	14.3	16
Tensile strength at yield TD		Mpa		19.6	18.4	19
Elongation at break MD		%		523.5	447.1	495.1
Elongation at break TD		%		562.4	505.6	534
Elongation at yield MD		%		6.8	5.8	6.3
Elongation at yield TD		%		6.1	7.5	6.8
Oxygen permeability		Cc/ m^2/ day				≤900
Water vapour permeability		g/ m^2/ day				≤2

Table 2. Specifications of the developed barrier film (type 2) 120 micron

Property		Unit	Method	Value		
				Max.	Min.	Mean
Average thickness		µm	DIN 53370	121.6	119.8	120.7
2 SEGMA thickness tolerance		%		5.6	3.8	4.7
Width		mm	Internal	442	442	442
Coefficient of	out/out	-------	ASTM D	0.40	0.36	0.38
friction	IN/IN		1894	0.20	0.18	0.19
	NTR/M		ISO 8295	-	-	-
Surface tension		Dyn/CM	DNI ISO 8296	-	38	-
Tensile strength at break MD		Mpa	ASTM D882	50.2	42.2	46.6
Tensile strength at break TD		Mpa		46.1	41.2	43.4
Tensile strength at yield MD		Mpa		19.1	15	17.3
Tensile strength at yield TD		Mpa		21.8	20.4	21
Elongation at break MD		%		569.4	475.7	531.7
Elongation at break TD		%		591.6	524.5	563.2
Elongation at yield MD		%		7.8	6.7	7.3
Elongation at yield TD		%		8.1	7.1	7.8
Oxygen permeability		Cc/ m^2/ day				≤450
Water vapour permeability		g/ m^2/ day				≤2

Table 3. Specifications of the developed barrier film (type 3) 140 micron

Property		Unit	Method	Value		
				Max.	Min.	Mean
Average thickness		µm	DIN 53370	143	139	141
2 SEGMA thickness tolerance		%		2.2	2	2.1
Width		mm	Internal	442	442	442
Coefficient of	out/out	-------	ASTM D 1894	0.34	0.29	0.32
friction	IN/IN			0.46	0.41	0.44
	NTR/M		ISO 8295	-	-	-
Surface tension		Dyn/CM	DNI ISO 8296	-	38	-
Tensile strength at break MD		Mpa	ASTM D882	42	40	41
Tensile strength at break TD		Mpa		38	36	37
Tensile strength at yield MD		Mpa		17	16	16.5
Tensile strength at yield TD		Mpa		575	560	567.5
Elongation at break MD		%		580	555	562.5
Elongation at break TD		%		550	525	537.5
Elongation at yield MD		%		14	13	13.5
Elongation at yield TD		%		14	13	13.5
Oxygen permeability		Cc/ m^2/ day				≤0.1
Water vapour permeability		g/ m^2/ day				≤2

Fig.1. The laboratory store used for assesment of the proper poly-ethylene films

Equipment and measuring procedure:

Determination of wheat grain moisture content (%w.b):

The moisture content of the wheat grain samples were measured by the standard air oven method according to AACC (2000). 10 grams of wheat grain samples were placed in an electric oven at 130oC for 16 h and then they were kept in a desecrator at the room temperature.

Ambient air temperature and relative humidity (for storage tests):

The universal digital measuring equipment (Model Kaye Dig. 14) connected to 32 channels scanning box with thermocouple sensors distributed at different locations of the storage room was used to measure the air temperatures. The relative humidity meter (Model Ex-Tech) was used to measure the air relative humidity at adjacent points of temperature measurements

Monitoring grain bulk temperature:

Grain bulk temperatures at different locations of the stored stocks were measured at different locations of each stock using Octtemp thermocouple data logger.

Monitoring CO_2 concentrations:

CO_2 concentrations **was** monitored every one week using a CO_2 sensor (VI GAZ " Gas analysis – model Box 121,(VI GAZ Company, France).

Tests to Evaluate Grain Quality:

The quality evaluation tests may be assessed as follow:

Protein content (%).(Eynard *et al* 1994)., Fungal and total microbial colony counts, cfu/g. Samson *et al*. (1996) ,Insect count,(insect/kg) (AOAC, 2000) and Alpha Amylase Activity/Falling Number, (Sec), AACC (2000).

RESULTS AND DISCUSSION

Ambient air temperature and relative humidity:

Fig. (2) Presents the average recorded data of ambient air temperature and relative humidity during the period of storage process (June-Oct 2014). As shown in the figure, the average ambient air temperature ranged from 18.36 to 27.6 oC and the relative humidity ranged from 62.7 to 75.3% during the period of storage tests.

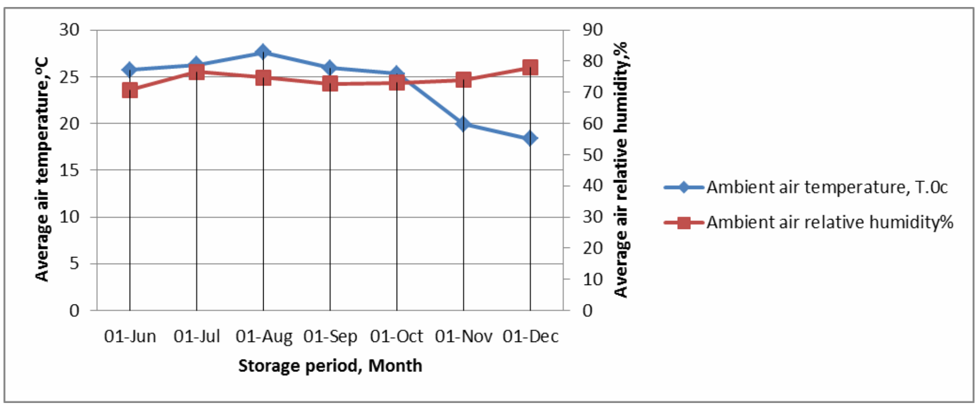

Fig. 2. Change in ambient air temperature and relative humidity during the Lab scale storage period

Grain bulk temperature:

Grain bulk temperature at different types of storage bags surface showed distinctive pattern of the ambient air temperature throughout the season. As shown in Fig. (3), the temperature oscillation decreased with the grain depth inside each tested stock. The recorded average grain bulk temperature ranged from 19.04 to 34.66, 17 .11 to 32.40, 17.64 to 32.5, and 20.34 to 35.72 oC for the storage bags type 1, 2, 3 and the burlap bags respectively.

Grain moisture content:

The change in grain moisture contents depends on the initial moisture content, the entrance of moisture from outside through the surface of plastic bags due to permeability and the moisture released from the respiration process. As shown in Fig. (4), the grain moisture content decreased in different rates for all types of tested bags. However, it was decreased during the first 4 months of storage for the grain stored in burlap bags (the summer time) and starts to increase again during the last two months due to moisture absorption from outside and the higher rate of respiration. The recorded moisture content for different studied types of bags during the storage period ranged from 10.97 to 12.60, 12.45 to 12.60, 12.51to 12.60 and from 11.04to 12.60% w.b. for the plastic bags type 1 , type 2 , type 3 and the purled bags respectively. This means that, the storage bags (Type 3), could keep the grain moisture content without noticeable variations followed by the bags type (2). While both bags type 1 and the burlap bags showed moisture variations due to higher permeability of bags materials to the surrounding air condition.

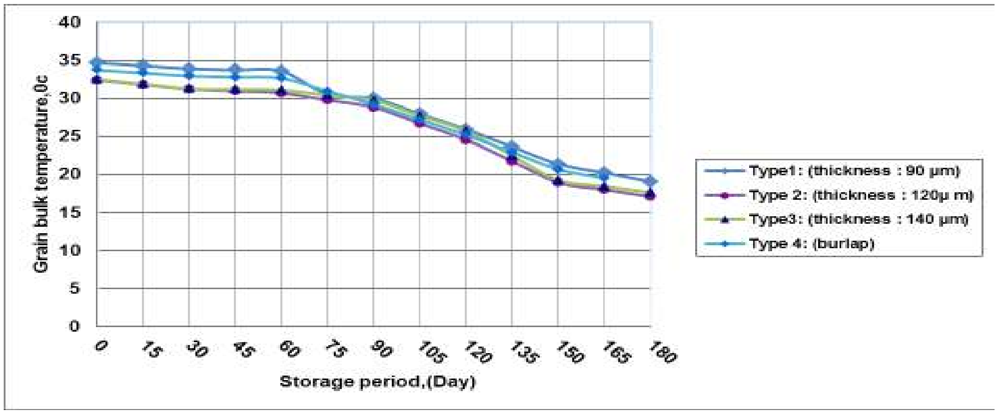

Fig. 3. Change in grain bulk temperature as related to storage time.

CO_2 concentration inside different types of bags:

The respiration of grains, fungi, insects and other microorganisms present in the grain ecosystem consume O_2 and generate CO_2, heat and water. The movement of gases into and out of the bags depends on the gas partial pressure differential and the permeability through the plastic materials. As shown in table (4), CO_2 concentration was varied with the type of bags grain condition. The results show that, plastic bags (Type 3) showed the highest levels of CO_2 concentration which increased from 0.2 to 21.8% followed by the bags type (2) which showed an increase of CO_2 level from 0.2 to 18.1%. However both the plastic bags (type 1) and burlap bags showed CO_2 levels ranged from 0.2 to 11.7 and from 0.2 to 0.3% respectively.

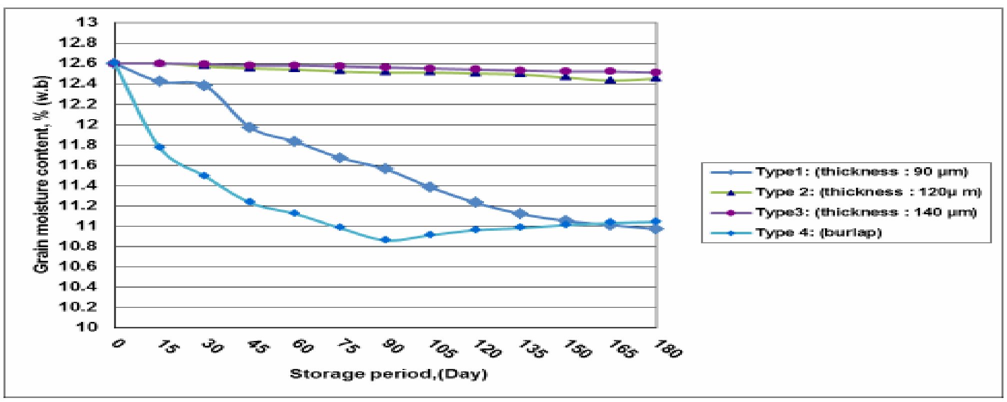

Fig 4. Change in grain moisture content as related to storage time .

Table 4. Change CO_2 concentration ,% as related to storage time at different type of bag as related to storage time .

Time, day	CO_2 concentration ,% Type1: (thickness : 90 µm)	Type 2: (thickness 120µ m)	Type3: (thickness : 140 µm)	(burlap)
0	0.2	0.2	0.2	0.2
15	2	5.3	7.2	0.3
30	5.1	7.7	9.6	0.2
45	6.4	11.2	14.7	0.3
60	8.6	14.5	17.4	0.2
75	10.2	15.3	19.8	.0.3
90	11.9	17.1	21	0.3
105	11.9	17.1	21	0.3
120	12.2	18.7	23.8	0.2
135	13.1	19.5	25.2	0.2
150	12.2	19.1	23.4	0.3
165	11.8	18.4	21.9	0.2
180	11.7	18.1	21.8	0.2

Microbial Count:

The contamination levels recorded at the closing of any type of bags suggest that contamination with molds and other microbes are dependent on grain conditions. Under the storage conditions in different types of studied poly-ethylene bags, the mold activity is basically stopped, and the else mycotoxin production as the level of CO2 increased. As shown in Fig. (5), the total microbial load at the end of storage period approached 21000 , 10000, 9000 and 72000 cfu/g for the grain stored in plastic bags Type 1 , 2 and 3 and the burlap bags respectively. This means that, both grain bags type 2 and 3 recorded very close values of total microbial count may eliminate the fungal growth rate during the storage time.

Insect count inside the bags:

The reasons for insect development in storage bags is limited due to most of the bags are filled with grain coming directly from the field. When grain is stored O_2 concentration can drop below the 2% and the CO_2 concentration can rise above 20%, creating a lethal environment for insects. As shown in table (5), both of storage bags type (2) and (3) were almost free of insects all-over the storage period without any fumigation. However both, the plastic bags (Type 1) and the burlap bags recorded an increase rate of insect count, where the insects continued viable in the plastic bags type 1 and they were counted viable in a certain period of storage time and dead in other count time due to fumigation process (two time fumigation were done).

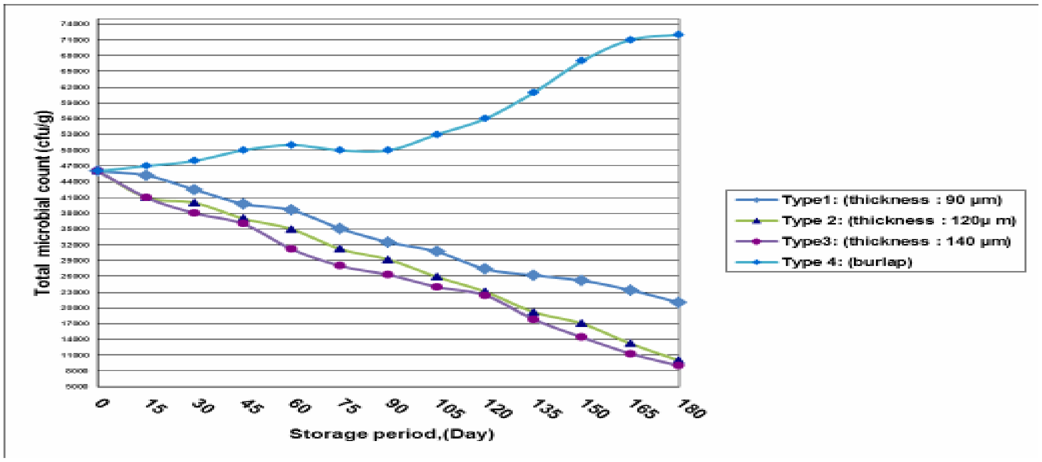

Fig. 5. Total microbial count (cfu/g) as related to storage time.

Table 5. Insect count as related to storage time for different types of storage bags .

Time, day	Type1: (thickness : 90 µm)	Type 2: (thickness : 120µ m)	Type3: (thickness : 140 µm)	Type 4: (burlap)
0	0	0	0	0
15	0	0	0	0
30	0	0	0	0
45	0	0	0	6
60	2	0	0	10
75	3	0	0	14(dead)
90	3	0	0	12(dead)
105	4	0	0	18
120	7	0	0	16
135	9	0	0	19(dead)
150	12	0	0	27
165	17	0	0	29
180	20	0	0	32

Protein content of wheat grain:

Table (6) presents the changes in protein content of the grain stored at different types of storage bags as related to storage time. As shown in the table, the protein content ranged from 10.92 to 11.69, 10.64 to 11.93, 11.65 to 11.98 and 10.35 to 11.63 % d.b. for grain stored in plastic bags Type 1, 2 and 3 and burlap bags respectively. In general the protein content not greatly affected by the storage method. Meanwhile, all the stored samples recorded protein level over 10% **as** recommended by the Egyptian Standard No. 1601-1/2010.

Table 6. Protein content of wheat grain,%(d.b) as related to storage time .

Time, day	Moisture content of wheat grain from different type of bags			
	Type1: (thickness : 90 µm)	Type 2: (thickness : 120µ m)	Type3: (thickness : 140 µm)	Type 4: (burlap)
0	11.85	11.85	11.85	11.85
15	11.69	11.87	10.84	11.63
30	11.53	11.89	11.83	11.41
45	11.37	11.91	11.81	11.19
60	11.21	11.93	11.80	10.97
75	11.08	11.67	11.78	10.81
90	10.95	11.42	11.79	10.66
105	10.98	11.34	11.76	10.61
120	10.93	11.53	11.79	10.90
135	11.03	11.12	11.74	10.37
150	10.92	11.41	11.71	10.86
165	11.52	10.64	11.98	10.35
180	10.96	10.99	11.65	10.71

Falling No. of wheat grain:

Table (7) presents the changes in falling No. of the grain stored grain at different types of storage bags as related to storage time. As shown in the table the falling No. ranged from 326 to 361, 336 to 363, 341 to 364 and 357 to 355sec. for grain stored in different types of studied bags Type 1, 2 and 3 and burlap bags respectively. In general grain samples stored in all types of bags recorded falling No. over 300 sec. at the end of storage period which is not causing a sprouting damage as recommended by Sarhad et. al, 2010 and the Egyptian Standard No. 1601-1/2010 .

Table 7. Falling number of wheat grain, (sec) as related to storage time.

Time, day	Type1: (thickness : 90 µm)	Type 2: (thickness : 120µ m)	Type3: (thickness : 140µm)	Type 4: (burlap)
0	364	364	364	364
15	356	358	364	355
30	349	353	364	338
45	341	347	364	338
60	334	341	364	329
75	330	340	364	326
90	328	337	362	323
105	326	347	362	322
120	326	336	362	330
135	341	350	362	342
150	361	363	364	357
165	328	360	341	341
180	329	359	364	324

RECOMMENDATIONS

The overall results indicate that dry grain (M.C less than 13% w.b.) can be stored in the developed poly-ethylene bags (type 2 and 3) for more than six months without losing quality.

- Storing dry grain in storage bags (Type 2 and 3) did not create a lethal environment for insects, molds and total microbial load. In general bags type 3 showed more moisture sealing and less permeability for CO_2 in comparison with type (2) and (1)
- Further tests for both storage bags Type 2 and 3 are recommended in larger storage scale for longer storage period to assess the safe storage period of each type.

REFERENCES

AACC.(2000).Approved Methods of American Association of Cereal Chemists,10th ed. American Association of Cereal Chemists, st. Paul, MN.

Adler C, Corinth H G and Reichmuth C. Modified atmospheres. In Subramanyam Bh and Hagstrum D W ed. (2000).Alternative to pesticides in stored-product IPM. Boston: Kluwer Academic Publisher, 106-146.

AOAC - Association of Official Analytical Chemist. (2000). Natural Toxins. Official Methods of AOAC International. Volume 2, Chapter 49, 1-64. 17th edition. (Edited by William Horwitz).

EYNARD, L., GUERRIERI, N., and CERLETTI, P. (1994). Determination of wheat proteins in solution by dye binding in flour, dough and bread crumbs. Cereal Chem. 71:434-438.

FAO (2017). FAOSTAT, © FAO Statistics Division 2017, January 2017.

Navarro, S., (2006). Modified Atmospheres for the control of stored-product insects and mites. In: Heaps, J. W. (Ed) Insect Management for Food Storage and Processing, Second Edition, AACC International, St. Paul, MN, USA, pp. 105-146.

Navarro, S., Finkelman, S., Sabio, G., Iskber, A., Dias, R., Rindner, M., Azrieli, A., (2002). Enhanced effectiveness of vacuum or CO2 in combination with increased temperatures for control of storage insects, In: Credland, P.F.A., Armitage, D.M., Bell, C.H., Cogan, P.M., Highley, E. (Eds), Proceedings of the Eighth, International Working Conference on Stored-product Protection, 22-26 July 2002, York, UK, CAB International, Wallingford, UK, pp. 818-822.

Samson, R.A; Hoekstra, E.S; Frisvad, C. and Filterborge, O. (1996). Introduc on of food borne fungi. 5th ed., Central bureau voor Schimmelcultures born. Delfet. Netherland.

Villers P, Navarro S, De Bruin T (2008). Recent developments in hermetic storage technology using sealed flexible storage structures. In: Daolin G, Navarro S, Jian Y, Cheng T, Zuxun J, Yue L, Haipeng W [Eds.] Proc 8th Int Conf Controlled Atmosphere and Fumigation in Stored Prod. California Garden Hotel, Chengdu, China. Sept. 21-26. 2008, Sichuan Publishing Group, Sichuan, China. 649-654

التخزين الآمن لحبوب القمح المصري بإستخدام أنواع مختلفة من الأجولة البلاستيكية النوعية

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تهدف الدراسة إلي تقليل الفاقد الكمي والنوعي للقمح المصري أثناء عملية التخزين في المخازن والشون المفتوحة عن طريق إستخدام طريقة جديدة مبتكرة وإقتصادية .تعتمد تلك الطريقة علي كفاءة التحكم في المحتوي الرطوبي للحبوب والفطريات والبويضات الحشرية الموجودة بالقمح خلال فترة التخزين بإستخدام ثلاث أنواع مختلفة من الأجولة البلاستيكية النوعية من حيث التركيب الكيميائى والخصائص الطبيعية والميكانيكية وكذلك سمك طبقة الفيلم المصنع منة الأجولة 90,120,140) ميكرون (للنوع الأول والثانى والثالث على التوالى .تم أيضا مقارنة هذه الانواع من الاجولة الخيش المستخدمة في تخزين القمح بالطرق التقليدية.وقد تم اجراء تجارب التخزين باستخدام قمح حديث الحصاد) صنف جميزة (9 تم حصادة من المزرعة التجريبية لمركز ميكنة الارز بميت الديبة بكفر الشيخ خلال موسم الحصاد .2015-2014 وخلال فترة التخزين والتى امتدت الة حوالى 6 أشهر تم قياس التغير في المحتوى الرطوبى للحبوب ودرجات الحرارة وكذلك نسبة ثانى أكسيد الكربون داخل الأجولة بالاضافة الى خصائص الجودة للقمح المخزن للوصول الي أنسب نوع من الاجولة يمكن استخدامه في التخزين علي النطاق التطبيقي .واوضحت النتائج ما يلي:عدم توفر البيئة المناسبة لزيادة المحتوى الرطوبى للحبوب وكذلك النموات الفطرية والحشرية نتيجة لانخفاض درجة حرارة كتلة الحبوب وزيادة نسبة ثانى أكسيد الكربون داخل الأجولة من النوعين الثاني والثالث مما أدى الى عدم وجود أية اصابة حشرية مع انخفاض الحمل الميكروبى مقارنة بالأجولة البلاستيكية من النوع الأول سمك 90 ميكرون (والأجولة الخيش. أمكن تخزين القمح عند محتوي رطوبي أبتدائي أقل من 13% علي اساس رطب بصورة آمنه كامل لمدة تزيد عن 6 شهور بإستخدام الاجولة البلاستيكية النوعية من النوع الثاني والثالث دون فقد فى أى من خصائص الجودة للحبوب المخزنة مع عدم الحاجة الي إجراء عملية التبخير.تمكن النوع الثالث من الاجولة البلاستيكية النوعية) سمك 140 ميكرون (من الحفاظ علي المحتوى الرطوبى للحبوب المخزنة نتيجة لانخفاض درجة النفاذية للفيلم المصنع منة كما أدى الى ارتفاع تركيز غاز ثاني اكسيد الكربون وانخفاض الحمل الميكروبى دون ظهور أية نموات حشرية بالمقارنة بالانواع الاخري من الاجولة موضوع الدراسة مما يعنى إمكانية تخزين حبوب القمح لفترات زمنية تتعدى فترة التخزين للتجربة علي المستوي المعملي.يوصي بإختبار كل من النوع الثاني والثالث من الاجولة البلاستيكية النوعية في تخزين حبوب القمح علي النطاق التطبيقي ولفترات تخزين طويله لتحديد أقصى فترة للتخزين الآمن لكلا النوعين خاصة وأن كلاهما أعطي نتائج متقاربة خلال فترة الأختبارات المعملية 6) شهور.