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The Selection of Materials for Food Packaging *

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The first objective in selecting materials for food packaging is to determine as far as possible the requirements of the package in terms of usage and production. Some considerations which might be applied are listed in Table 1.

Table 1
Possible Requirements of a Package

Product Considerations
- Container Efficiency.
- Microbiological Factors.
- Water/Water Vapour Permeation.
- Gas Permeation.
- Fat Permeation.
- Sensitivity to Light.
- Temperature Variation.

Handling Properties
- Suitability for Machine Handling.
- Resistance to Processing.
- Facility for Distribution.

Economic Factors
- Basic Cost.
- Cost of Packaging Machinery.
- Rate of Operation.
- Down Time.
- Failure Rate.

Marketing Factors
- Appearance of Basic Package.
- Facility for Decoration and Modification (opening devices etc.)
- Maintenance of Appearance.
- Shelf Life.

Indirect Factors
- Toxicity.
- Taint/Odour.

Product Considerations. These are now generally appreciated. The first factor, container efficiency, i. e. the necessity for the package to retain the contents mechanically throughout the life of the package, in the factory, warehouse, whole-

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saler's, retailer's and ultimate consumer's premises has been the pre requisite of prepackaging since the earliest days of unit packaging.

Microbiological aspects of packaging are also well known, sterile packs dating back to the early days of food processing. More recently the application of flexible and semi rigid packages has become widespread. These have presented some new problems. Plastics materials carry a static charge which attracts dust with its attendant micro organisms, particularly mould spores. These resulted in product spoilage when plastics containers for edible fats were first marketed. Mould spores in materials used as anti-block dusts for flexible envelopes have also given rise to microbiological growth in suitable foodstuffs.

Control of water permeation is a primary factor in selection of materials for many products. Minimum permeability is required for dried foods where wetting results in loss of quality, and also for liquid emulsions containing water which may break down if the phases become unbalanced due to its loss. High water vapour permeation is, however, desirable in packages for some products such as sausages and fresh horticultural produce. Control of gas permeation is of particular current interest with the advent of the prepackaging of more sophisticated foods. Cured meats and cheese require to be packaged so that a low oxygen tension is maintained in the pack to prevent the growth of aerobic micro organisms. Some dried products such as chicken meat and shell fish currently being produced by Accelerated Freeze Drying techniques are subject to chemical oxidative deterioration and these likewise need a low oxygen tension in the atmosphere surrounding them. Fresh meats require the presence of oxygen to maintain a good colour.

Fat permeation has been the subject of study for many years and requires no comment.

Sensitivity of some products to light is also well known and the use of opacified packages is desirable to prevent photo oxidative process in edible fats.

The use of packages to control temperature variation has so far been little employed. However, frozen foods and particularly ice cream could be advantageously marketed in packs which would keep the product cold for a limited period. The advent of inexpensive insulating materials which can be suitable fabricated, such as foamed plastics, may result in the development of such packages.

Handling Properties. The selection of materials with specific handling properties has only recently received special scientific study. With the advent of high speed machinery the necessity for materials which will run continuously without breakdown is becoming a paramount production requirement. Thus some materials are selected for their folding characteristics, foil laminates for fat wrapping are embossed, and cartonboard for use for cartons for high speed cartonning lines selected for its facility for cutting and creasing. Frictional characteristics of materials and resistance to impact failure, together with controlled stress/strain properties are also being specified.

A new application is the use of flexible and semi flexible materials for use with in-pack pasteurisation or sterilisation. Hence materials and package properties may now require to be determined after processing (normally heat treatment but also possibly irradiation).

Finally in this section comes the handling properties of materials during distribution. This is closely allied to container efficiency on the one hand and marketing factors on the other. Materials such as aluminium foil may be subject to corrosion under unfavourable circumstances.

Economic Factors. The operation of the majority of these factors is self evident and although of the highest importance requires little elaboration in a paper such as this.Generally speaking with large production the capital cost of equipment is of minor importance compared with efficiency and speed. Furthermore with high speed lines it is normally desirable to obtain optimum machine performance even if this involves slight extra expense in packaging materials. Marketing considerations such as «Brand Image» enter into failure rate assessment which cannot therefore be judged solely on the grounds of crude economics.

Marketing Factors. The necessity for the modern packaging to sell itself when on display results in a number of scientific considerations
Cartonboard must be selected to give a good square carton which retains its shape. Materials must accept elaborate decoration and this may necessitate specially finished smooth surfaces, controlled ink absorption, etc. Furthermore materials may be selected for their suitability for incorporation of tear strips or other similar novelties.

Indirect Factors. This heading is intended to cover all factors which do not readily fit into the categories listed above. It includes inter alia interactions between packaging materials and products. These are becoming of more importance with the increasing diversity of packaging materials used and products packed.

The possibility of ingestion of toxic components derived from packaging materials is one which has exercised authorities throughout the world. In the earlier days of prepackaging the prime concern, apart from isolated materials like can lacquers and wad facings for caps, was with poisoning by heavy metals; thus P. V. C. stabilised with lead compounds was never, to the writer's knowledge, used extensively for food packaging. Nevertheless, it is only in comparatively recent years that printing inks based on heavy metal inks have been discouraged for use on flexible packaging materials, it being argued that they did not come into contact with a products if applied to the outer surface of a packaging material. This assumption is now considered not always acceptable. It is not unknown for children to chew ice cream wrappers, nor for set-off to occur in printing so that the inner surface of material becomes contaminated. Finally envelopes containing dried foods are sometimes accidentally dropped into hot water with the contents. For this reason The Society of Printing Ink Manufacturers, after consultation with the Food Manufacturers Federation and Cocoa, Chocolate and Confectionery Alliance, issued recommendations to their members that they should not sell inks based on a number of known toxic pigments for use for certain types of food package.

There are now also a vast profusion of complex organic materials in use. Thus plastics materials may contain basic polymers, plasticisers, stabilisers, antistatic agents, slip or antislip additives, processing lubricants, antiblock compounds, pigments or colouring materials, etc. The plastics industry has been well aware of the problem of toxicity and from the outset the large polymer manufacturers carried out extensive toxicity testing.

Although not necessarily presenting toxicity problems, packing materials can result in the impairment of the palatability of food products in many ways. Perhaps the most obvious are from foreign odours tainting a product. Residual solvents in printing inks have been accepted for many years by Food Manufacturers as causing taint in sensitive foods such as chocolate, edible fats, etc. and different standards must be applied to different types of foodstuffs in this respect. Also in an allied field is direct contamination of a food by leaching. It will be appreciated that this type of deterioration is of particular difficulty with the complex packaging materials. Thus the minor additives in a plastics material are probably not known to the Food Manufacturer and may be changed by suppliers without the knowledge of their customers. Such changes could well have serious effects with packs with extended shelf life where the build up in off-flavour may develop slowly so that a large volume of packs has been produced before it becomes apparent.

Packaging materials may also contain substances which promote deterioration of products, the most well known being pro-oxidants such as iron and copper ions in edible fat wrappers.

Finally the product may result in deterioration of the package. Leaching may result in embrittlement of the packaging material or affect the stability of printing inks which will smudge and even spread.

Having considered the factors of importance to a Food Manufacturer when marketing a packaged product the principle need is to determine how these factors can be assessed.

There are two types of tests used for such assessment; the first type are instrumental measurements on materials and the second tests of performance on finished packages. The former type of test procedures rely on well developed methods, giving usually numerical results of known repeatability. The latter comprise a number of standardised procedures, usually developed for testing outer cases and tests developed primarily for specific applications by individual Materials' Suppliers and Food Manufacturers. Storage tests must also be included amongst performance tests and these are performed in one way or another by most Food Manufacturers.

Materials Tests

Substance Weight and Caliper. These give one of the best guides for quality control of materials in both economic and technical aspects and are almost universally determined.

Measurement of strength properties of materials is also extensively performed. The most common tests include:

Tensile Strength Measurements. Generally in these tests the breaking load and elongation at break are measured by slowly increasing the load on a test strip until failure occurs. More elaborate and expensive instruments will, however, produce complete stress/strain curves.

Mullen Bursting Strength. This measurement derived from the paper industry is very popular as being easy to perform with well documented techniques and average performance data.

Both the above tests, however, measure properties of limited direct value to a materials user, probably data of most direct use covers the relationship between extensibility and load which may be a factor affecting packaging machinery performance.

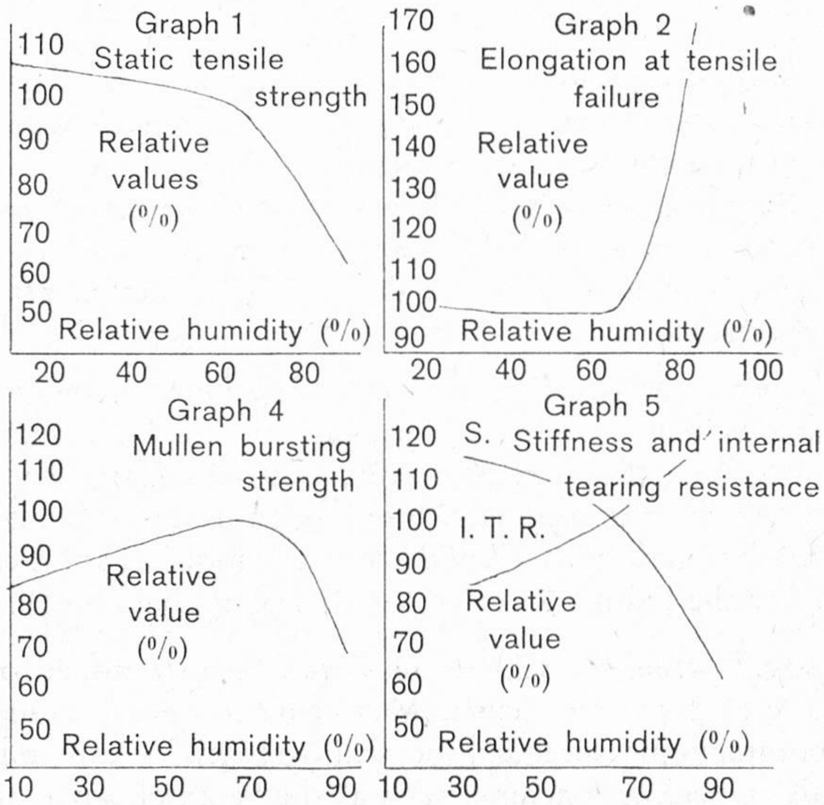
Impact Strength or Dynamic Tensile Strength. This measurement is of more value as tensile failure of package in use, or a material on a machine, usually results from the virtual instantaneous application of a load. The pendulum type test which was originally used for this measurement cannot be used for very extensive materials. Hence other techniques have been developed for these. Typically the Falling Dart Test may be employed for plastics films.

Seal Strength. Seal strength can be determined on preformed seals by either Static or Dynamic Tensile Measuring techniques. One of the major difficulties in laboratory measurement of seal strength is the initial production of standard seals, as sealing machines such as the Sentinel range of instruments providing controlled pressure, accurate temperature setting, and precise timing are too expensive for the average user laboratory. Additionally or alternatively seals made on standard factory production equipment can be used providing this is set up for the material under test and allowed to run until steady conditions are achieved. For production purposes the most suitable material is one that will give satisfactory seals over a range of operating conditions, this being generally more important than a high optimum value.

Lamination Strength. This is normally determined by Static Tensile Strength Measurement using a peeling technique similar to that used for Seal Strength assessments.

Stiffness. Measurements of stiffness are normally made with instruments giving empirical results. It may be important in assessing handling characteristics and marketing potentialities of a package. It has also been found that creasing efficiency can be affected to some extent by rigidity so that cartonboards with a high ratio between machine and cross direction stiffness may be less satisfactory on certain production machinery due to uneven creasing. Whilst this particular problem is readily overcome by altering the creasing stet forme for any particular type of carton it is indicative of difficulties which might occur if converters change the type of cartonboard they are using.

Other mechanical measurements include Tearing Resistance, various types of flexing tests etc. These are often derived from paper industry tests and may not measure the significant properties for packages.



Graphs indicating variation in physical characteristics of sulphite paper, 70 g/m² at 20 °C
Value at 65 % r. h. = 100 %

It is important to perform these tests under use conditions. Thus tensile properties of fibrous materials vary with relative humidity as is shown in Graphs 1 to 5. These show a number of interesting features. For instance although static tensile strength falls as relative humidity increases, elongation prior to failure increases and thus the energy required to cause a break (measured by Dynamic Tensile Strength) increases to a maximum at about 80 % r. h.

Mullen Bursting Strength increases with relative humidity to a maximum at 65 % r. h. and then falls rapidly.

Stiffness values fall as relative humidity increases but Internal Tearing Resistance increases.

Many plastics materials show considerable strength variation with temperature, polypropylene in particular, but other polymers also, becoming embrittled at low temperature due to changes in their crystalline structure.

Water Vapour Permeability. This can be determined by a number of well known tests of the dish type. The one in general use in the United Kingdom is the Patra test. In recent years more elaborate equipment has been devised in order to obtain results more rapidly. Whilst this object has been achieved, the speed at which such tests can be performed is limited because of the necessity for a sample to achieve equilibrium conditions before measurements are made, although pre-conditioning can be employed to facilitate this. The other limitation of such tests is that they are normally performed singly whereas dish determinations can be performed if necessary, fifty at a time with one set of equipment. Hence the overall productivity with the newer techniques is normally lower.

Again in some circumstances, particularly low temperatures, tests should be performed under use conditions. It is not possible with some materials to extrapolate to assess low temperature permeability from results obtained on standard ambient condition measurements. This is illustrated in Table 2. Thus at 25 °C / 75 % r. h. for uncreased material 3 > 2 > 1 whereas at —23 °C 1 > 2 > 3.

Table 2
Cartons for frozen foods

	Water vapour permeability of material				Weight loss (%) on storage for 12 weeks (carton filled with vegetables)
	25 °C / 75 % r. h.		— 23 °C / mm Hg.		
	plain	creased **	plain	creased	
Coating 1. Pure wax: 23 g/m²	1,1	19	21	23	17,8
2. Modified wax: 20 g/m²	2,0	21	7,9	9,1	5,6
3. Polythene: 0,0015 in.	2,6	2,8	<0,5	<0,5	0,3

** Using crease lines present in cartons ca. 3800 cm/m².

Gas Permeability. Measurement of this property has been dealt with at length in recent years. The results given in Table 3 of this report were obtained by using a modified ASTM method described earlier (1). In the opinion of the writer this technique has now probably been supersceded by isostatic techniques of the type which use a carrier gas and recirculate the atmosphere through a gas detector which is coupled to a recorder.

Measurement of gas permeability of regenerated cellulose film at the operative relative humidity is important, the relationship between permeability and relative humidity for PT cellulose film being shown on Graph 6.

Numerous methods for measurement of fat permeation have also been described. The earlier ones designed primarily for vegetable parchment indicated the number of pores in this type of material. Fat permeation into or through continuous material with which it interacts is more difficult to measure. One technique

Table 3

Basic film type	Polyester (Polyethylene terephthalate)	Polypropylene biaxially orientated	Polythene irradiated (shrinkable)	Polythene H. D. (3)	Polythene L. D. (4)
Caliper (0,001 in)	1,1	0,95	1,2	2,0	2,0
W. V. P. 25/75	7,1	1,4	5,8		
$g/24$ h. m^2 38/90	17,4	5,4			
O_2 Permeability (dry)					
cc/24 h/m^2/atmos.	50	1480	>20,000	1000	4200
Tensile strength					
Kg./15 mm. MD (1)	5,7	5,0	3,0	1,3	1,3
CD (2)	4,6	5,0	4,8	1,0	No break
Impact strength MD	No break	No break			
cmKg. for 180×15 mm					
CD	No break	No break			
Mullen burst 1b/in²	95				
Seal strength 1b/in.	2,0	4,4		3,1	3,3
Substance g/m²	36	19	24		
Density g/cm³	1,38—1,39	0,89		0,95	0,918
Pasteurisability	Good	Good	Shrinks and becomes tougher	Good	Fair
Sterilizability	Good	Good	Shrinks and becomes rigid	Good	Poor
Low temperature properties	Good		Good	Good	Good
Oil resistance	Good	Good	Fair/Good	Good	Fair

Notes 1 Machine Direction
2 Cross Direction
3 Low Density
4 High Density
5 Medium Density

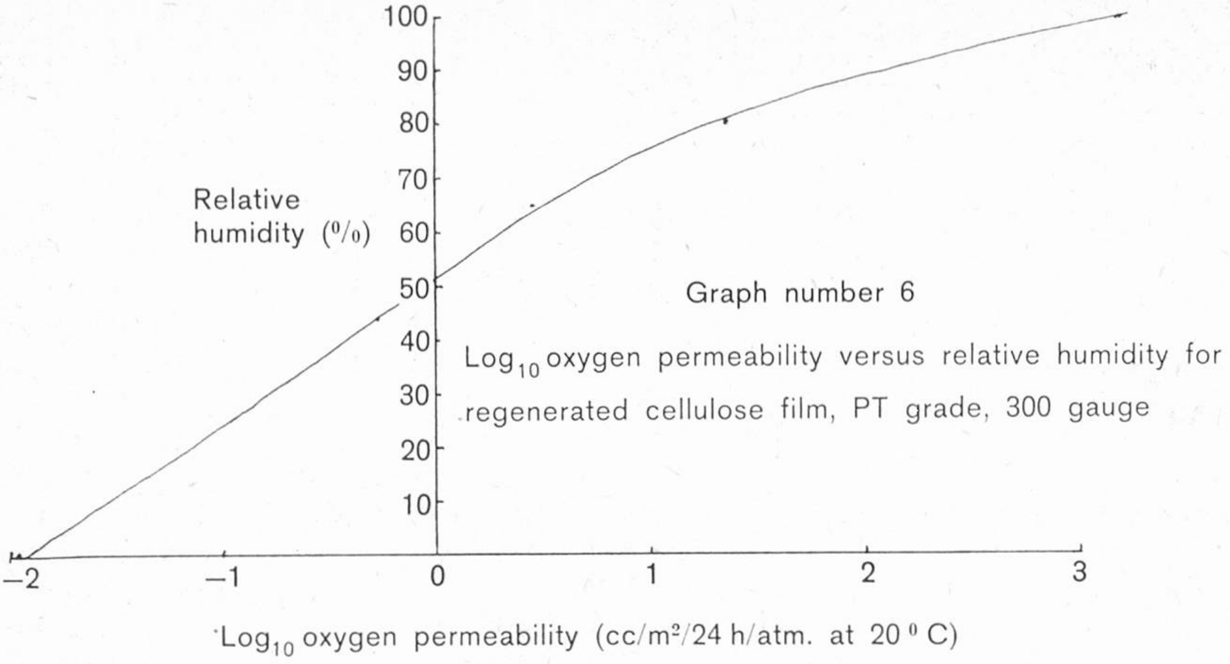
advocated for assessing absorption of fat by packaging material is to permit contact for a given time, then remove the fat and clean the surface of the material. Subsequently a saponification number determination is performed on the packaging material. This type of test does, of course, necessitate very careful standardisation of conditions, selection of test materials, etc. and as such is probably more suited to research purposes.

Polythene M. D. (5)	P. V. C.		Reg. cellulose		Nylon 6 (polycaprolactam)	Nylon 11 (poly W-amino undecanoic acid)	Rubber hydrochloride
	plast.	unplast.	MSAT	MXXT			
1,0	1,3	3,0	1,1	1,2	1,0	1,3	1,7
	19	4,8	2,0	0,4	10	12,2	2,9
			8,0	3,0	32		
5000		54	0,02		25	300	Literature figs. 70—1000
	1,9	14,0	3,5	4,0	2,2	4,0	1,7
	1,7	9,9	2,0	4,0	1,9	3,0	1,6
		2,2		11,0			No break
		1,2		3,4			No break
		58		61			Tough like p. e.
	3,6	8,1	0,5—1,0	0,5—1,0	1,3	5,1	3,4
	42	90	37	46	26	31	40
0,930		1,40	1,45	1,45	1,12	1,11	1,11
Good	Not suitable for food use	Good but opacifies	Good but perm'y. props. alter	Good but perm'y. props. alter	Good	Good	Good
Fair/Poor	Not suitable for food use	Good but opacifies	N/A	N/A	Good	Good	N/A
Good	Good	Fair	Good	Good	Good	Good	Good
Fair/Good	Plasticisers leached out	Good	Good	Good	Good	Good	Good

It is important where possible with all permeability tests to take specimens from the finished package as printing can particularly affect water and gas permeation characteristics and embossing may increase pinholing in parchment/foil laminates several hundredfold.

Other mechanical tests which Food Manufacturers perform where apposite cover such diverse measurements as the determination of the stability of print to dry, wet or greasy rub, or assessment of Cutting and Creasing efficacy.

Generally speaking an individual Food Manufacturer, although responsible in law for the safety of his packages, can do little actual toxicity testing. It is normal, therefore, in the U. K. to buy to an agreed specification for instance,



F & D. A. approved materials or those with toxicity limits designated in the British Plastics Federation publication (2). Large manufacturers can demand to know full details of the composition of any materials they purchase and thence make their own assessment of toxicity but suppliers may not necessarily provide such information to their smaller customers who, in any event, may not have the necessary technical knowledge or time available to make such assessments. They have, therefore, to rely on their suppliers.

Non toxic contamination must be assessed by Food Manufacturers. The safest way to carry out initial work is by storage testing, using the actual fully decorated packs to be marketed. For quality control and sorting materials, odour and taint testing can be performed. Methods are described in B. S. 375. Many different views are held on this subject and as with all arbitrary tests much thought should be given both to the food and packaging material under test when deciding on testing techniques. Tests may be made using actual food products or model systems. Suitable examples of the latter are those used in toxicity testing and details can be found in literature covering Toxicity Testing Procedures.

Generally contamination is assessed organoleptically but in a few instances direct measurement of chemical leaching into products can be made or undesirable components in packaging materials can be estimated, Where this type of measurement is possible it is very worthwhile.

To conclude this section a few properties of some common materials are listed in Table 3. This data is mainly derived from examination of samples taken from one delivery from one supplier and hence although measurements were precise in themselves it should only be used to give the order of magnitude which may be anticipated.

Performance Tests

Unfortunately in many instances standard tests on materials cannot be used to predict the performance of packages. Thus failure of moisture proof or gas tight packs may occur through seal failure or delamination. Hence performance tests, although less precise numerically, are often to be preferred. The term performance test covers an extensive range of concepts and in the remainder of this paper these are briefly discussed.

The first type, most widely known, must be storage tests either under simulated storage, accelerated storage or constant average conditions. For all these tests it is possible to use laboratory made containers or production containers. The advantage of the former is that they usually give less variation in results and indicate the best performance which can be anticipated. However, laboratory made packages are often made with sample materials which are undecorated and they do not, per se, indicate production variation nor production handling problems although it is possible by suitable treatment of packages, using compression, dropping, vibration, etc. to build a «model» product handling sequence into tests with laboratory prepared packages. This is always worthwhile for major tests. Testing production materials requires very careful statistical design and extensive sampling if anything approaching a true pattern is to be achieved. Furthermore testing several different packages or materials necessitates considerable effort in resetting lines to obtain optimum performance for each. It is also difficult to use model standardised food products e. g. desiccants.

Simulated storage normally implies cycling conditions which are very difficult to obtain with normal storage equipment. Generally the best that can be achieved is to switch the temperature control device on and off with a time switch to give heating and cooling. As the necessity for such tests usually occurs with a liquid product giving in-package evaporation and condensation and/or with packs where external condensation is an important factor this technique is adequate. For most purposes, however, even condition testing is to be preferred. This type of testing is practised in most accelerated storage trials. These can often be calibrated fairly accurately over a period of time. It has been found that storage at 25 °C 75 % r. h. gives an acceleration factor of about three over average marketing conditions in the U. K. for hygroscopic products and similarly a dehydration factor of three is obtained by storing aqueous based products at 25 °C 20 % r. h. Unfortunately loss of components other than water such as alcohols or esters in temperature controlled and accelerated storage can result in a product having a different non-aqueous composition to the same product which had lost the same quantity of water under marketing conditions. This is certainly true with extreme acceleration employing very high or low temperatures or relative humidities, and results from such tests should be interpreted very cautiously. With low temperature testing, storage in comparatively empty forced draught test cold rooms gives an acceleration factor over commercial forced draught stores of about three and over still stores of six in terms of dehydration.

Another type of performance test is a transit trial followed by controlled storage or some kind. This requires no further comment.

Performance tests may include testing of completed packages for water vapour permeation or gas permeation in standard laboratory equipment. This is very worthwhile because it often enables differences between predictions from tests on materials and results from normal storage tests to be explained. It is the only way that seal areas can be adequately tested and also allows for general rough handling, but nevertheless gives accurate results for single parameters. This type of test is easily performed for measurement of water vapour permeability but until recently to study gas permeation of packages required repetitive gas analyses over a time period, or use of some «artificial» gas such as nitrous oxide as the contained gas if rapid results were required. For simple tests of this type indicator paper such as phenol red paper can be sealed in packages which are then exposed to a reactive gas (ammonia for phenol red paper). After a given time the papers are removed and examined. Colour changes occurring indicate the presence and location of flaws in the package. Recently a technique has been described using the isostatic gas permeablility measuring equipment which promises to be a valuable addition in this field (3).

Lastly specific facets of performance particularly on machinery are studied by simulated tests. Special creasing might be applied to a specimen such as occurs when a machine folds a wrapper. Then the efficiency of the material in respect of creasing may be judged by an arbitrary measurement such as torque against a feeler arm or degree of spring-back. Another example of this type of test is to compress, extend and twist a material by a controlled mechanical process and then examine its permeability characterististics, print stability or other parameters by suitable tests. Such procedures are devised by Food or Machinery Manufactures specifically for their own plant or production lines. The will undoubtedly become more widespread as packaging becomes even more sophisticated and can be very valuable provided the purpose for which they were initially designed is kept to the forefront and they are not applied out of context.

Summary

The paper discusses in general terms the requirements which might need to be satisfied by a package for food product indicating with a few examples some of the requirements of particular types of foodstuffs or packaging material with special reference to the newer types of packaging.

The second part of the paper indicates the type of test procedure which are used for assessing packaging materials.

Classical and performance tests, including storage tests, are discussed with some indication of the advantages and limitations of each test. Typical results are illustrated in tables and graphs.

Résumé

On examine tout d'abord de manière générale les exigences auxquelles doit satisfaire un emballage pour denrées alimentaires. Puis on passe en revue les diverses méthodes utilisées pour examiner les divers matériaux d'emballage, en indiquant leurs avantages et limitations.

Zusammenfassung

In dieser Arbeit werden eingangs die allgemeinen Anforderungen geprüft, die an eine Lebensmittelverpackung gestellt werden. In einigen Beispielen werden dann die besonderen Anforderungen an das Packmaterial, insbesondere an die neueren Verpackungsstoffe, besprochen. In einem zweiten Teil der Arbeit werden die verschiedenen Untersuchungsmethoden für Packungsmaterialien angegeben. Zahlreiche Prüfverfahren, einschließlich Lagerungstests, werden diskutiert im Hinblick auf ihre Vorteile und Beschränkungen. Typische Resultate werden in Tabellen und graphischen Aufzeichnungen wiedergegeben.

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Vacuum Packaging of Coffee in Flexible Foil Laminates *

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Roasted coffee as a luxury is judged by its odour, taste and flavour, while its stimulating effect is due to the content of caffeine and other organic nitrogen compounds. Caffeine as a chemically very resistant compound requires no special packaging, but all the aromatic substances produced in the roasting process are very sensitive to oxygen and moisture. Most of these aromatic compounds, especially organic sulphides, aldehydes and ketones are very susceptible to oxidation, losing their flavour by reaction with oxygen. We also know that coffee contains considerable amounts of oil and fatty compounds with flavour-bearing molecules dissolved in the oily phase of the coffee. This gives an explanation why rancidity is produced as soon as coffee has come into contact with air. All the oxidation reactions are accelerated by light rays, higher temperature and moisture. We must

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